USE OF INCIDENT DATABASES FOR CAUSE AND CONSEQUENCE ANALYSIS AND NATIONAL ESTIMATES

A Thesis

by

A.S.M. OBIDULLAH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Chemical Engineering

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Approved by:

Chair of Committee,	M. Sam Mannan
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ABSTRACT

Use of Incident Databases for Cause and Consequence Analysis and National Estimates. (December 2006)

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Chair of Advisory Committee: Dr. Sam Mannan

Many incidents have occurred because industries have ignored past incidents or failed to learn lessons from the past. Incident databases provide an effective option for managing large amounts of information about the past incidents. Analysis of data stored in existing databases can lead to useful conclusions and reduction of chemical incidents and consequences of incidents. An incident database is a knowledge based system that can give an insight to the situation which led to an incident. Effective analysis of data from a database can help in development of information that can help reduce future incidents: cause of an incident, critical equipment, the type of chemical released, and the type of injury and victim. In this research, Hazardous Substances Emergency Events Surveillance (HSEES) database has been analyzed focusing on manufacturing events in Texas from 1993-2004.

Between thirteen to sixteen states have participated in the HSEES incident reporting system and it does not include all the near miss incidents. Petroleum related incidents are also excluded from the HSEES system. Studies show that HSEES covers only 37% of all incidents in the US. This scaling ratio was used to estimate the total universe size.

DEDICATION

To my wife Saida Sultana

And

All my family members in Bangladesh

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my advisor, Dr. M. Sam Mannan, for his endless support throughout my two years of study. Over the past two years of my master's study, his guidance and encouragement have supported me in completing this work. I would like to express my appreciation to Dr. Mahmoud El-Halwagi and Dr. Marietta Tretter for serving as my committee members.

I want to express my appreciation to Mike O'Connor for his constant support in my research. I am thankful to Julie Borders for her ideas and comments about my research. I am thankful to Maureen F. Orr and Perri Zeitz Ruckart for their ideas about my research which is inspired by their paper "Surveillance of Hazardous Substances Release Due to System Interruptions, 2002". I am also thankful to Dr. William J. Rogers for his comments. I also express my appreciation to all the staff of the May Kay O'Connor Process Safety Center as well as the staff of the Chemical Engineering Department for their help. At last, I thank my family and friends for their moral support.

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CHAPTER I

INTRODUCTION

1.1. Introduction

Incidents in chemical process industries can involve injuries, fatalities or property damage. Severe incidents can occur anywhere toxic and/or flammable materials are stored, transported or used; however, they are most common in chemical manufacturing or storage facilities.

An incident can be defined as "the sudden unintended release of or exposure to a hazardous substance that results in or might reasonably have resulted in, deaths, injuries, significant property or environmental damage, evacuation or sheltering-in-place[1]". A hazardous substance is defined as "any chemical, including a petroleum product, that is toxic, reactive, flammable, asphyxiating, or that presents a potential hazard to people, the environment, or property because of pressure or temperature[1]."

All chemical incidents have causes and consequences. Severity of the incident depends on the magnitude of its consequences. The consequences of an incident could be short term or long term depending on the nature of the incident. Trend analysis, cause analysis and consequence analysis of past incidents is an important tool in preventing the recurrence of similar incidents. Significant events include the Bhopal Disaster of 1984, which released a highly toxic gas at a pesticide facility and killed more than 2,000 people[2]. This incident had long term consequences on human health.

The Bhopal disaster resulted in an emphasis on safety management systems throughout the world. In the United States, concerns over this and other incidents led to the passage of the 1986 Emergency Planning and Community Right-to-Know Act.

This thesis follows the style of Process Safety Progress.

The EPCRA requires local emergency planning efforts throughout the country, including emergency notifications[3].

The law also requires companies to make information about their storage and processing of toxic chemicals publicly available so that citizens can identify critical zones where hazardous releases could occur.

With an increasing number of incidents, process safety has become an important issue for everyday operations in the process industry. The study of case histories provides valuable information to chemical engineers involved with safety. This information can be used to improve safety culture that can help in reducing incidents in the future. A list of some important major incidents is given below.

Flixborough, England

The incident at Flixborough, England occurred on Saturday, June 1, 1974. A 30 ton vapor cloud of cyclohexane exploded destroying the Nypro cyclohexane oxidization plant at Flixborough, killing 28 people, and injuring thirty six[4]. Other plant on the site were seriously damaged or destroyed and fifty three people off-site were injured.

Pasadena, Texas

A series of explosions and fires occurred in a petrochemical plant in Pasadena, Texas, in 1989, in a polyethylene reactor killing 23 people and injuring 130[5]. The explosion occurred when a seal blew out on an ethylene loop reactor releasing ethylene-isobutane. Eighty five thousand pounds of ethylene, isobutene, hexane and hydrogen vapors were released and exploded.

Seveso, Italy

In 1976, a chemical plant explosion near Seveso, Italy, resulted in the highest known exposure to 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD) in a residential area.

An uncontrolled exothermic reaction caused the explosion, resulted in the release of an aerosol cloud containing sodium hydroxide, ethylene glycol, and sodium trichlorophenate.

The toxic vapor cloud dispersed to six kilometers long and one kilometer wide covering a densely populated area. The incident did not cause any immediate casualties but thirty seven thousand people were exposed to the chemical and around eighty thousand animals died [2].

Mexico City, Mexico

In November 1984, a series of BLEVEs (Boling Liquid Expanding Vapor Explosion) at an LPG Terminal near Mexico City resulted in 650 deaths and over 6,400 injuries[6]. The estimated property damage was $31.3 million. The rupture of a pipeline caused series of BLEVEs at the LNG terminal. The emergency shutdown procedures were initiated too late to prevent the catastrophe.

Piper Alpha

Piper Alpha was a North Sea oil production platform operated by Occidental Petroleum Ltd. On July 6, 1988 a leakage of gas condensate which had built up under the platform ignited, resulting in a massive explosion. The entire platform was engulfed by fire due to the released gas. One hundred sixty seven people died during the incident, while only 62 crewmen survived [4].

Incident prevention is the key to minimizing injury to people at work. Learning from past incidents is an essential element in incident prevention. Use of incident databases for trend analysis, cause and consequence analysis, and lessons learned are an important approach to preventing the recurrence of incidents and overall improvement of safety performance. In this study, analysis of HSEES database is used to demonstrate a cause, trend and consequence analysis of incidents.

1.2. Process Safety Management

Releases of hazardous chemicals in processes have been reported for many years. Incidents continue to occur in various industries that use highly hazardous chemicals which may be toxic, reactive, flammable, or explosive. Process Safety Management is the application of management principles and systems for the identification, understanding, and control of process hazards to prevent process-related injuries and incidents. Process Safety Management is a regulation developed by the U.S. Occupational Safety and Health Administration (OSHA), which intends to prevent catastrophic incidents. Industries and government recognize process safety management as an effective approach to help reduce incidents and the severity of incidents if it is understood and implemented as intended [5].

The PSM standard has 14 major elements:

- Employee Participation
- Process Safety Information
- Process Hazard Analysis
- Training
- Operating Procedures
- Contractor Safety
- Pre-Startup Safety Review
- Mechanical Integrity
- Hot Work Permit
- Management of Change
- Incident Investigations
- Emergency Response & Planning
- Compliance Audits
- Trade Secrets

Detailed description of the PSM regulation and the requirements for each element is provided elsewhere [7].

1.3. Incident Investigation

Incident investigation is an element in the PSM requiring employers to investigate, within 48 hours, incidents which did result or could have resulted in catastrophic releases of covered chemicals [5]. Incident investigation is a key for the learning process and can prevent the recurrence of similar events. Near-miss incident investigation can prevent serious injuries, fatalities and damages. Incident investigation is a process that should find facts and not simply seek to place blame on employees.

> Accident investigation is like peeling an onion or, if you prefer a more poetic metaphor, the dance of the seven veils. Beneath one layer of causes and recommendations, there are other, less superficial, layers. The outer layers deal with the immediate technical causes while the inner layers are concerned with ways of avoiding the hazards and with the underlying causes such as weaknesses in the management [8].

An investigation is conducted by a team comprised of several people who are knowledgeable about the process involved. The composition of the team depends on the severity of incident and size of the plant. The team investigates and analyzes the incident and develops a written report on the incident. Reports must be retained for five years.

While incident investigation of individual incidents offer specific lessons and root causes of incidents, much more can be learned from analyzing the universe of incidents. The challenge is acquiring the incident databases, and developing the appropriate methodology to vet, mine, and then analyze the information. In this study, the Hazardous Substances Emergency Events Surveillance (HSEES) database maintained by the Agency for Toxic Substances and Disease Registry (ATSDR) has been analyzed to develop conclusions regarding causes and consequences.

CHAPTER II

BACKGROUND

According to Trevor Kletz, "We forget the lessons learned and the accident happens again. We need better training, by describing accidents first rather than principles, as accidents grab our attention, we need discussion rather that lecturing, so that more is remembered; we need databases that can present relevant information without the user having to ask for it [9]."

An incident database is a powerful tool that can help reduce future incidents. Incident databases contain information that can help to identify the causes of the incident, chemical involved, and type of incident, etc. In the last 30 years, special attention has been given to database mining, designing, developing and populating databases, some focusing on specific region and some focusing on specific areas of interest[10].

Over the past several years, chemical incidents have become a major issue for chemical processing plants. A broad range of groups from industries, federal, state, and local government agencies, environmental groups, and concerned citizens want to learn more about these accidental releases. They often asked questions- where, when, and how the releases have occurred. Their ultimate goal is to determine why such releases occur and how to prevent them in the future. Past incident data have been collected by a number of different public and private sources to meet this large public demand for information about chemical releases. After the Bhopal incident in 1984, the US Environmental Protection Agency (EPA) enacted a rule requiring each regulated facility to develop a Risk Management Program, which includes detailed hazard assessment of an accidental release and an accident history of the last five years [11]. Approximately 15,000 facilities were required to develop an RMP and submit it to the EPA by June 1999 [12].

Based on certain criteria, the Federal government started collecting accidental release information, such as the type of chemical released, industry category, and impact of the release (death, injury, and property damages), etc[13]. Apart from the EPA Risk Management Program, other federal incident databases are listed below:

Table 1. Federal accidental release databases

Acronym	Database	Lead Agency
IRIS	Incident Reporting Information System	NRC
ERNS	Emergency Response Notification System	EPA
ARIP	Accidental Release Information Program	EPA
HMIRS	Hazardous Materials Incident Reporting System	DOT
HLPAD	Hazardous Liquid Pipeline Accident Database	DOT
IMIS	Integrated Management Information System	OSHA
HSEES	Hazardous Substances Emergency Events Surveillance	ATSDR

Analysis of data from databases can provide effective lessons for reducing future incidents. A systematic approach should be used for data analysis. Several past works have been done on data analysis. “Novel Applications of Data Mining Methodologies to Incident Databases [14]” by Anand examined a subset of data from the National Response Center’s (NRC) incident database focusing on fixed facility incident in Harris County, Texas. “Model for Multi-strata Safety Performance Measurements in the Process Industry [15]” by Keren analyzed propane-related incidents in the US. There are numerous incidents during plant startup/shutdown, maintenance, and process upset time.

Orr and Ruckart from HSEES analyzed events during plant startup/shutdown, process upset, and maintenance time for 2002 [16]. The Hazardous Substances Emergency Events Surveillance (HSEES) system was established by ATSDR, collects and analyzes information about releases of hazardous substances and publishes annual reports, and fact sheets, etc [17, 18].

Many incidents recur not because they cannot be prevented, but because the organization does not perform the proper incident investigation. Due to missing data, systematic approach being is not often used when incidents occur at the workplace, thus we lose many opportunities for learning from the past [19].

The process safety incident database provides an effective tool for managing the large amounts of information that can help reduce future incidents. The development of chemical incident databases is considered an important step in chemical incidents analysis. The objective of this study is to analyze the HSEES database and develop recommendations for the industries to prevent future incidents. This study focuses only on incidents in manufacturing facilities in the Texas.

CHAPTER III

METHODOLOGY

Incidents, injuries and fatalities normally follow a pattern. This pattern can be described by the incident pyramid as shown in Figure 1. A number of studies have shown there is a statistical relationship between different incident types. At the top of the pyramid are incidents with the most severe consequences (injuries, fatalities, loss of production, property damage)[5]. Incidents with the least consequences are found at the bottom of the pyramid.

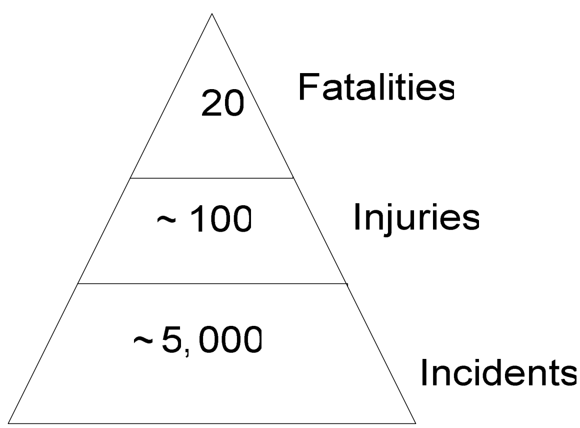


Figure 1. Incident pyramid

As mentioned earlier, the HSEES database was used in this study to perform incident data analysis. Thirteen to sixteen participating state heath departments collect data on each hazardous substance release event. Information about location and industry involved in the release, factors contributing to the release, chemical released, victim, injury and evacuation information, are entered into the standardized web-based application system maintain by ATSDR (Agency for Toxic Substances and Disease Registry)[17].

Information about the hazardous substance release is collected from variety of sources such as records and reports of state environmental agencies, NRC (National Response Center), DOT (Department of Transpiration), police and fire departments, and hospitals.

Hazardous substances emergency events are defined as uncontrolled or threatened releases of hazardous substances. Release of exclusively petroleum products are excluded this definition. Events were recorded when the amount of substance released, or threatened released that might have been released, needed to be removed, cleaned up, or neutralized according to federal, state, or local law [17]. Victims were defined as those individuals who suffered at least one injury or died as a result of the event. In counting injuries, one victim could have been more than one injury. Events were classified as transportation related when they occurred during transportation (surface, air, or water) of hazardous substances. Fixed-facility events were classified as the events occurring at industrial sites, schools, farms, or any other type of facility.

Substances were grouped into 11 categories: acids, ammonia, chlorine, bases, mixtures, paints and dyes, pesticides, polychlorinated biphenyls, volatile organic compounds (VOCs), other inorganic substances, and other substances[20]. The “mixtures” category consists of chemicals from different categories, and the “other” category consists of chemicals that cannot be defined into any one of the other 10 chemical categories. All other inorganic substances except acids, bases, ammonia, and chlorine are classified as “inorganic substances”.

HSEES collects data from different sources in the four different files in the both Microsoft Excel and Access format in each year. These files are the event file, chemical file, injury file, and victim file. File integration technique was used for effective data analysis.

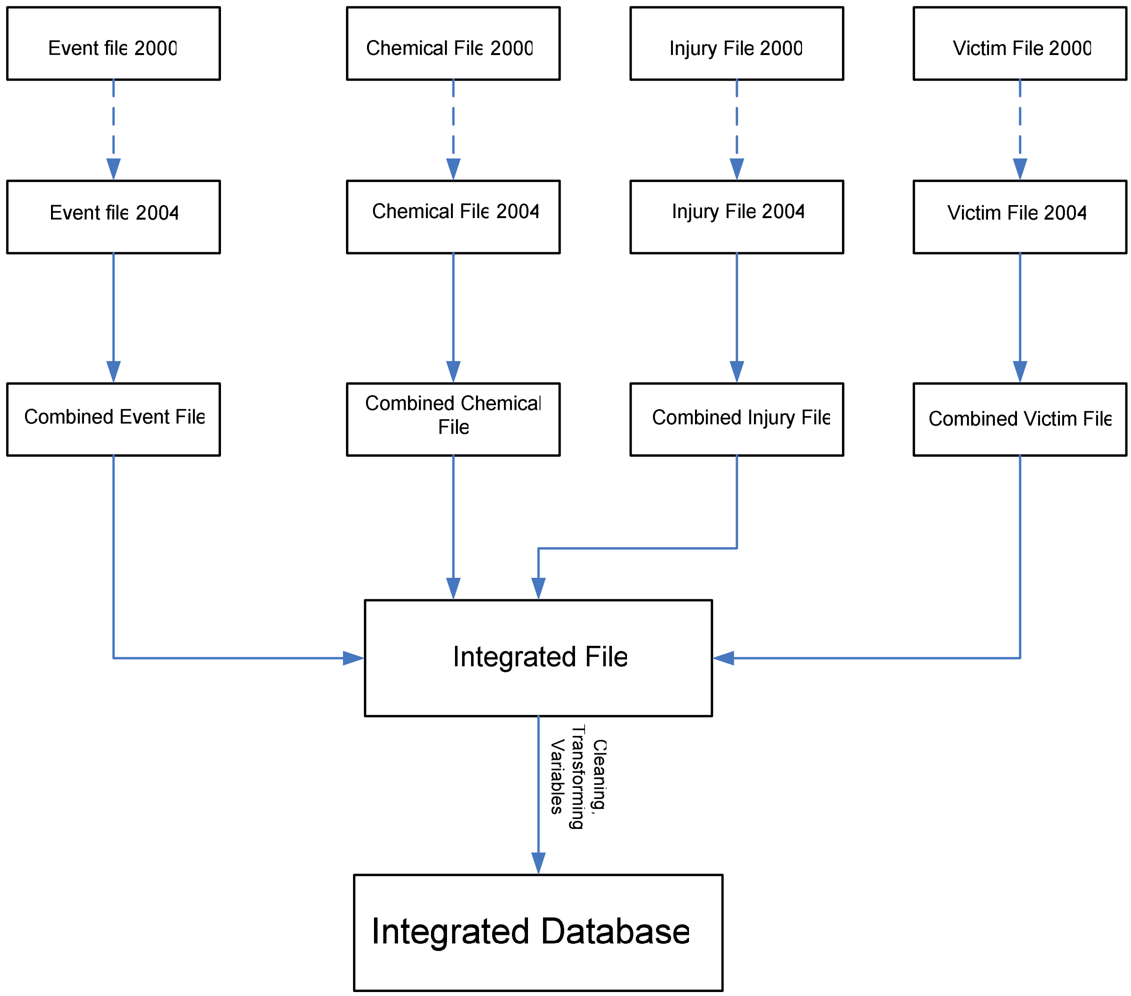


Figure 2. Database integration

Figure 2 shows the file integration technique that was used for this study. The event, chemical, injury, and victim files for different years were first combined separately to get the four separate files. Then, the four separate combined event, chemical, injury and victims files are integrated into a single file. It was really challenging to combine the files, because these files contain different variables and the file formats vary. The event file has the unique identity (ID) for each event. But, the injury, victim and chemical file have repeated ID based on the number of injuries, victims and released chemicals.

Microsoft Access was used to separate the unique ID from these files. Integrated database was generated after cleaning, and transforming the variables from the integrated file.

Incidents were classified into two categories: system interruption and system comparison event. Interruption events are defined as the interruption of the normal chemical processing procedure in manufacturing industries [16]. System interruption is considered any immediate cause of either system or process upset (PU), startup/shutdown (SS), system maintenance (ME), power failure (PF) and fire and explosion (F&E). All other manufacturing events except interruption events are called Comparison events. It compares with interruption events in the manufacturing industries to describe the problem and identify potential risk factors that can be targeted for prevention [16]. Comparison events are found by subtracting the system interruption events from the total events.

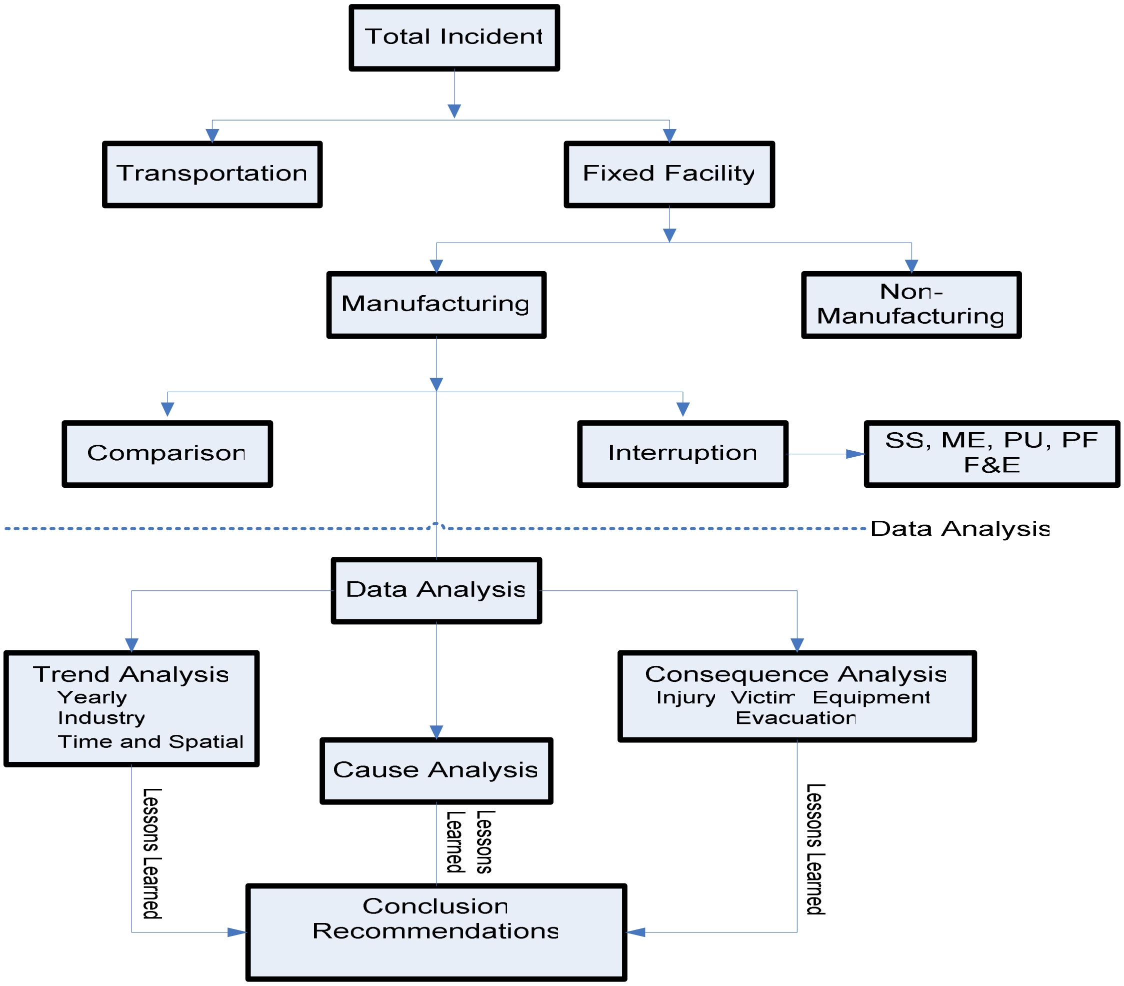


Figure 3. Data classification and analysis

This flow diagram in figure 3 describes the procedure used for data analysis. The total number of incidents is divided into two categories: fixed facility incidents and transportation incidents. Fixed facility incidents were further divided into two categories: manufacturing and non-manufacturing events. As mentioned earlier, manufacturing incidents in Texas were considered for this study. Manufacturing incidents were divided into two categories: Interruption and Comparison events. The incident database was analyzed by performing trend analysis, cause analysis, and consequence analysis of the manufacturing events. Finally recommendations are given to the industries based on the results of analysis.

CHAPTER IV

INCIDENT DATABASES

4.1. Background

The development of chemical incidents databases is considered an important step in incident analysis. Analysis of data stored in existing databases can lead to useful conclusions and assist chemical incident mitigation. Databases contain lot of information that can help to identify process safety trends, underlying causes of incidents, critical parts of the plant, and chemical severity, etc. Incident databases are an effective risk management tool that can identify process safety weaknesses and help risk managers determine where special focus should be given [21]. Chemical incident databases can be used as a knowledge-based system for measuring industrial safety performance [22]. A reactive chemical database can help to increase awareness of existing hazards and provide tools to reduce those hazards [23]. Special focus has been given to designing, developing and populating databases in the last three decades. In spite of considerable efforts, several deficiencies have been reported regarding the number of incidents covered, as well as, the accuracy of the available information. However, experience has shown chemical incidents databases can be used for effective incident management, analyzing trend, national estimates, emergency management, reducing risk, and hazard analysis that can help reduce future incidents. HSEES database has been used in this study focusing on manufacturing incidents in the Texas.

4.2. Hazardous Substances Emergency Events Surveillance (HSEES) Database

Hazardous Substances Emergency Events Surveillance (HSEES) was established by the Agency for Toxic Substances and Disease Registry (ATSDR) in 1990. This database is an active, state-based system to describe the public health consequences associated with the release of hazardous substances [17].

The database was developed because ATSDR determined that the public health consequences of hazardous substance releases have not been adequately characterized by other databases.

During 1993-2004, 79372 events were reported from participating states.

The overall goals of the project are:

- To describe the distribution and characteristics of hazardous substances emergencies.
- To document the nature of injuries and fatalities related to these events.
- To identify risk factors associated with injuries and fatalities.
- To identify strategies that might reduce future injuries and fatalities from the release of hazardous substances.

Thirteen to sixteen state health departments (Alabama, Colorado, Iowa, Louisiana, Minnesota, Mississippi, Missouri, New York, New Jersey, North Carolina, Oregon, Rhode Island, Texas, Utah, Washington, and Wisconsin) collected data for HSEES. Information about the incidents is collected from environmental protection agencies, police and fire departments, the US Department of Transportation, the National Response Center, and hospitals. Once a hazardous substance emergency has occurred within a participating state, the state agency notifies the health department within 48 hours. The state health department then collects information about the emergency on a data collection form and enters it into a program. The data collection forms are designed by ATSDR. All data were computerized using a Web-based data entry system provided by ATSDR.

Principal Data Elements:

- Time, date, and day of the week
- Location of the incident
- Event type (fixed-facility or transportation-related event)
- Factors contributing to the release
- Environmental sampling and follow-up health activities
- Specific information on injured persons: age, sex, type and extent of injuries, distance from spill, population group (employee, general public, responder, student), and type of protective equipment used
- Land use and population information to estimate the number of persons at home or work who were potentially exposed
- Evacuation and Sheltering
- Released material (Type of material, quantity)
- Area/Equipment Type
- Contingency Plan and others

Other databases have been developed in the past several years. Different databases focused on different issues, such as specific region, specific incidents, etc. Information in the databases also varies based on their scope of work. Table 2 compares HSEES database elements with other federal databases elements.

Table 2. Comparison of data elements in federal hazardous substance release databases (Source: EPA User's Guide to Federal Accidental Release Databases)

Data Category	Data Element	**Federal Databases**						
		IRIS	ERNS	ARIP	HMIRS	HLPAD	IMIS	HSEES
Event reporting information	*Reporting party*	√	√	√	√	√	√	
	Date and time reported	√	√		√	√	√	√
Facility/release location	*Facility name*	√	√	√	√	√	√	
	Facility Address	√	√	√	√	√	√	√
	Release location	√	√	√	√	√	√	√
Release Information	*Date and time of release*	√	√	√	√	√	√	√
	Transportation release	√	√		√	√		√
	Facility release	√	√	√			√	√
	Substance involved	√	√	√	√	√	√	√
	Quantity/concentration	√	√	√	√	√		√
	Affected medium	√	√	√				
	End result/type of release			√	√	√	√	√
Release Cause	*Primary Cause*	√	√	√	√	√	√	√
	Secondary Cause			√				√
	Equipment information	√	√	√	√	√	√	
Damages	*Deaths*	√	√	√	√	√	√	√
	Injuries	√	√	√	√	√	√	√
	Evacuation	√	√	√	√			√
	Property damage	√	√	√	√	√		
	Environmental damage		√	√	√			
Cleanup Action	*Stabilization and Control measures*	√	√	√				
	Notification	√	√	√	√	√		
	Prevention/Repairs	√	√	√		√		
General Remarks	*General Remarks*	√	√		√		√	

The information in the database is considered reliable because each data is verified by professionals through error-checking programs before entering into the main database. One of the important parts of the HSEES database is that the information about the injury and the victim is clearly defined as opposed to any other databases.

CHAPTER V

INDUSTRIAL CLASSIFICATION

5.1. Introduction

The purpose of an industrial classification system is to group industries according to common characteristics such that one can organize specific statistical information and to set criteria for deciding industrial policies. The statistical information includes identifying products, services and structures, data mining, and incident investigation, etc.

There are a number of classification schemes to identify industries such as the Standard Industrial Classification (SIC), the North American Industry Classification System (NAICS), the 1990 Census of population Industrial Classification System, and the Central Product Classification (CPS), etc. SIC and NAICS are commonly used to classify the manufacturing industries. The Standard Industrial Classification (SIC) is a United States government system that classifies industries by a three or four-digit code. Standard Industrial Classification Codes attempt to classify industries according to similarities in products, services, and production and delivery systems. The six-digit North American Industry Classification System (NAICS) replaces the 1987 Standard Industrial Classification (SIC). NAICS is a new classification system developed by the United States, Canada and Mexico in order to make a common industrial code in those three countries.

5.2. HSEES Industrial Classification System

Different databases and reference tools use different classification systems to organize their information. HSEES use 1990 Census of Population Industrial Classification system along with SIC codes. This study is focused on the following industrial codes which are shown in the table 3:

Table 3. Industrial classification

1990 Census Code	Industry Group	1987 SIC Code
192	Industrial and Miscellaneous Chemical	281, 286, 289
200	Petroleum Refining	291
180	Plastic, Synthetic and Resin	282

Further Classification of SIC Codes of these three industries are given below [24]:

281 Industrial Inorganic Chemical

- 2812 Alkalies and Chlorine
- 2813 Industrial Gases
- 2816 Inorganic Pigments
- 2819 Industrial Inorganic Chemicals, Cot Elsewhere Classified

286 Industrial Organic Chemicals

- 2861 Gum and Wood Chemicals
- 2865 Cyclic Organic Crudes and Intermediates, and Organic Dyes and Pig
- 2869 Industrial Organic Chemicals, Not Elsewhere Classified

289 Miscellaneous Chemical Products

- 2891 Adhesives and Sealants
- 2892 Explosives
- 2893 Printing Ink
- 2895 Carbon Black
- 2899 Chemical and Chemical Preparations, Not Elsewhere Classified

282 Plastic Synthetic and Resin Manufacturing

- 2821 Plastics Materials, Synthetic Resins, and Nonvulcanizable Elastom
- 2822 Synthetic Rubber (Vulcazizable Elastomers)
- 2823 Cellulosic Manmade Fibers
- 2824 Manmade Organic Fibers, Except Cellulosic

291 Petroleum Refining

- 2911 Petroleum Refining

CHAPTER VI

NATIONAL ESTIMATE

6.1. Introduction

The term "National estimate" is used for combining available data bases into national statistics. The national estimates approach is one of the best methods for developing specific decision based on current data. Incident databases do not contain all the incidents that occurred in the US. In this study, the term "national estimate" represents the total number of incidents in the US. National estimate would be found by using a statistically significant method. Statistical methods are reliable because by using the sample data, it will produce the result that is statistically significant.

The process of estimating the national estimate can be explained by different methods such as theory of sets, sampling adjust weight methods etc.

6.2. Sampling Adjust Weight Method

Sampling Adjust Weight Method is an effective method for estimating the total number incidents when some, but not all, of the incidents are included in the accident history database. One of the advantages of this method is that we can use only one database to estimate the universe size. A weight variable should be calculated for the database to be analyzed which contains information about the sample data.

Auxiliary information should be incorporated for improving precision and adjusting weight. The main purpose of adjusted weighting is to obtain as accurate parameter estimates as possible. This weight (scaling ratio) can be used to calculate the national estimate by the formula given below:

- National Estimate= Sample data*Weight (Scaling Ratio)

6.3. Scaling Ratio Calculation

Scaling ratio (weight) has been calculated by correlating HSEES incidents in the fourteen states with other auxiliary parameters such as RMP facilities, processes and incidents, US population, chemical workers, petroleum refining workers, and HMIS incidents as shown in the table 4. Linear Regression technique and weighted mean were used to calculate the scaling ratio.

Table 4. Correlation of incidents in the 14 HSEES states with other parameters

(Source: HSEES, RMP, and U.S. Census Bureau)

Data Collection States	HSEES	RMP	RMP	RMP	Population	Chemical	Petroleum Refinery	HMIS	Scaling Ratio Percent
	Incident	Facility	Process	Incident	million	Worker	Worker	Incident	
	2001	1994-1999	1994-1999	1994-1999	Census Bureau	2002 Economic Census	2002 Economic Census	2001	
Alabama	176	238	380	37	4.3	14,303	424	209	**37.3**
Colorado	196	244	283	19	4.0	7,049	0	352	
Iowa	315	987	1,014	31	2.9	6,664	153	178	
Louisiana	752	392	916	152	4.4	25,678	8,326	288	
Minnesota	356	552	711	17	4.7	8,380	0	284	
Mississippi	394	174	288	16	2.7	1,786	0	160	
Missouri	190	411	441	24	5.4	2,094	0	369	
New York	1,106	215	330	23	18.2	60,122	0	633	
N. Carolina	311	329	437	42	7.6	38,239	0	727	
Oregon	282	132	191	20	3.3	3,711	0	240	
R. Island	70	28	36	0	1.0	2,600	0	20	
Texas	2,771	1,415	2,414	192	19.7	73,833	16,872	1,249	
Washington	625	262	369	38	5.7	4,884	1,709	190	
Wisconsin	537	310	442	23	5.2	12,291	0	293	
Total	8,081	5,689	8,252	634	89	261,634	27,484	5,192	
Total for US	???	15,000	21,000	1,478	272	840,780	62,540	15,351	
Percent US	???	37.9	39.3	42.9	32.7	31.1	43.9	33.8	
R squared	???	0.52	0.74	0.65	0.73	0.70	0.79	0.71	

Calculation Procedure

- Determine all the parameters including the HSEES incidents for fourteen states as mention in the table for 2001.
- Determine the parameters for US except HSEES.
- Calculate Percentages of US (values of 14 states parameters/values for US parameters).
- Calculate coefficient of determination (R^2) for each parameters comparing with HSEES incidents.
- Calculate scaling ratio using weighted mean formula from R^2 and US percentages as variables.

Linear Regression

Coefficient of determination (R^2) is calculated by using linear regression technique. Linear regression describes the relationship between independent and a dependent variable. The goal of linear regression is to find the line that best predicts Y from X. By minimizing the sum of the squares of the vertical distances of the points from the line, linear regression predicts best value. The range of the data should be carefully observed while a linear regression model is fit to a group of data. By using a regression equation to predict values outside of the given range may yield incredible results. This technique is known as extrapolation.

Fitted linear regression model expressed by the given formula [25]:

$Y = \alpha + \beta X_i$ --- (1)

Y is the dependent variable (number of incident in HSEES)

X_i is the i^{th} independent variable (value of all other parameters)

The coefficient of determination (R^2) calculates the quality of fit. The following formula is used to determine the R^2

$R^2 = 1 - SSE/SST$-- (2)

SSE is the sum of squares of errors

$$SSE = \sum_{i=1}^{n} \left(y_i - \hat{y}_i \right)^2 \text{---} (3)$$

y_i is the observed value , $\hat{y}_i$ is the predicted value, and n is the number of observations

SST is the total corrected sum of squares of the data which is expressed by the following formula:

$$SST = \sum_{i=1}^{n} \left(y_i - \bar{y}_i \right)^2 \text{--} \quad (4)$$

Where $\bar{y}_i$ represents the average of the observed values of the dependent (target) variable

$R^2 = 1$ shows the perfect fit of the data.

Weighted Mean

The weighted mean is expressed by the formula given below:

$$\bar{W} = \frac{\sum X_i Y_i}{\sum Y_i} \text{--} \quad (5)$$

X_i = US percentages

Y_i = Coefficient of determination (R^2)

$\bar{W}$ = Weighted mean= Scaling ratio

CHAPTER VII

RESULTS

7.1. Incidents Distribution by Year

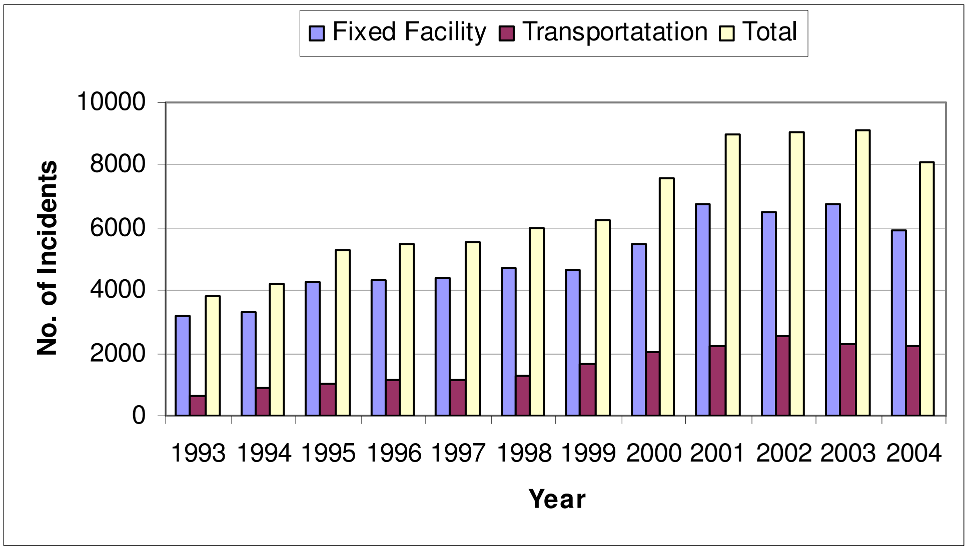


Figure 4. Iincidents distribution by year (Source: HSEES, 1993-2004)

Figure 4 represents the yearly fixed facility and transportation incidents. This figure shows that both the fixed facility events and transportation events are increasing each year with the exception of year 2004. In 2004, Alabama and Mississippi did not collect the data for the whole year. HSEES only collects incidents from thirteen or sixteen states and this figure does not represent the total incident trend in the US. HSEES did not collect all the near misses incidents from the participating states.

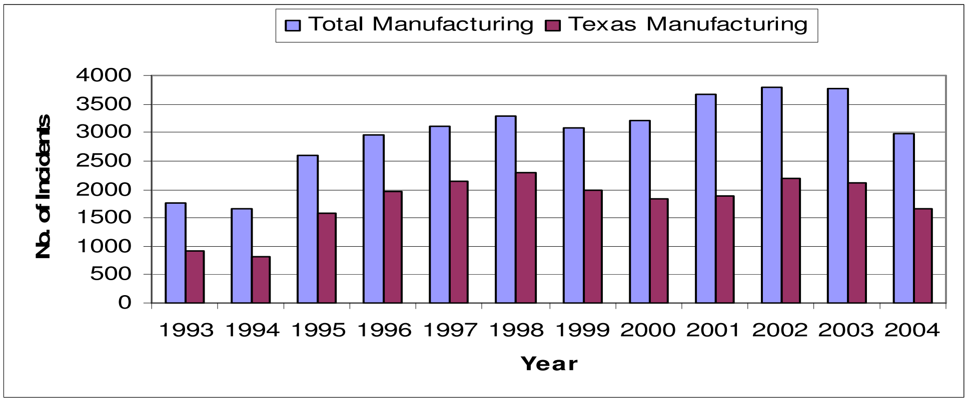


Figure 5. Distribution of manufacturing incidents by year (Source: HSEES, 1993-2004)

Figure 5 compares total fixed facility manufacturing events in all HSEES participating states with Texas fixed facility manufacturing events. Around 55-60% of the fixed facility manufacturing events occurred in Texas.

7.2. County Distribution

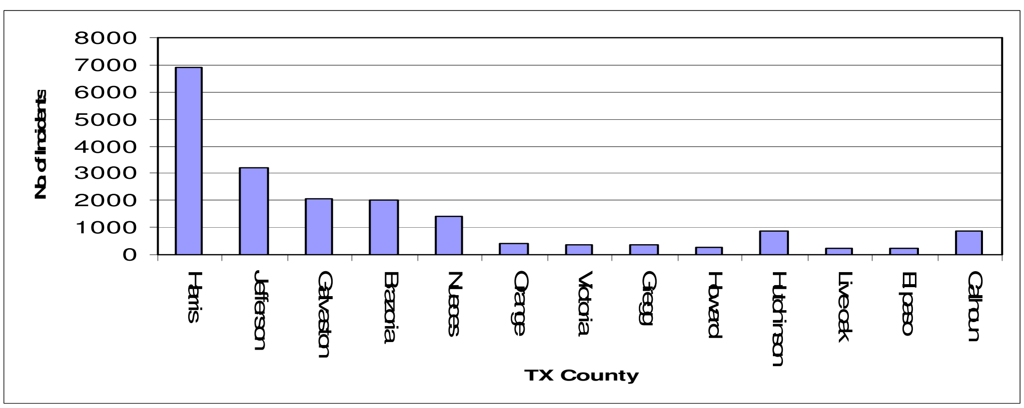


Figure 6. Distribution of manufacturing incidents by Texas counties (Source: HSEES, 1993-2001)

Figure 6 represents the county distribution of Texas fixed facility manufacturing events. Harris County (32%) has the highest number of incidents during 1993-2004. Texas counties along the gulf coast are highly industrialized and account for the largest number of incidents.

7.3. Incidents Distribution by Industry

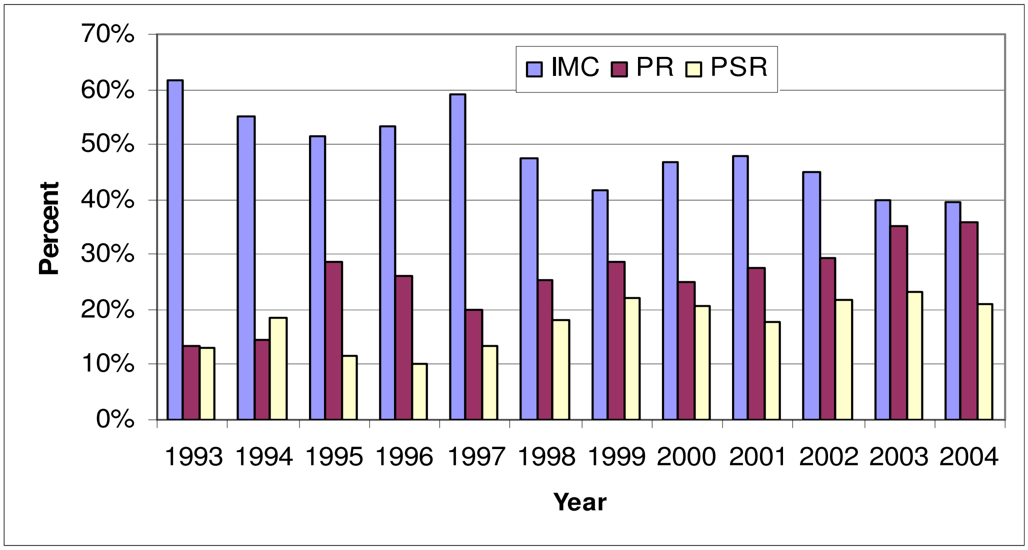


Figure 7. Industrial distribution of Texas fixed facility manufacturing incidents (Source: HSEES, 1993-2001)

Figure 7 represents the types of industries involved in Texas fixed facility manufacturing events. Most of the Texas manufacturing events occurred in the three industrial categories:

- Industrial and miscellaneous Chemicals manufacturing (IMC): SIC 281, 286, 289
- Petroleum and Refining (PR): SIC 291
- Plastic, Synthetic and Resin manufacturing (PSR) : SIC 282

It can be shown from the figure 7 that about 55%, 25%, 15% of Texas manufacturing incidents occurred in IMC, PR, PSR industries, respectively, during 1993-2004.

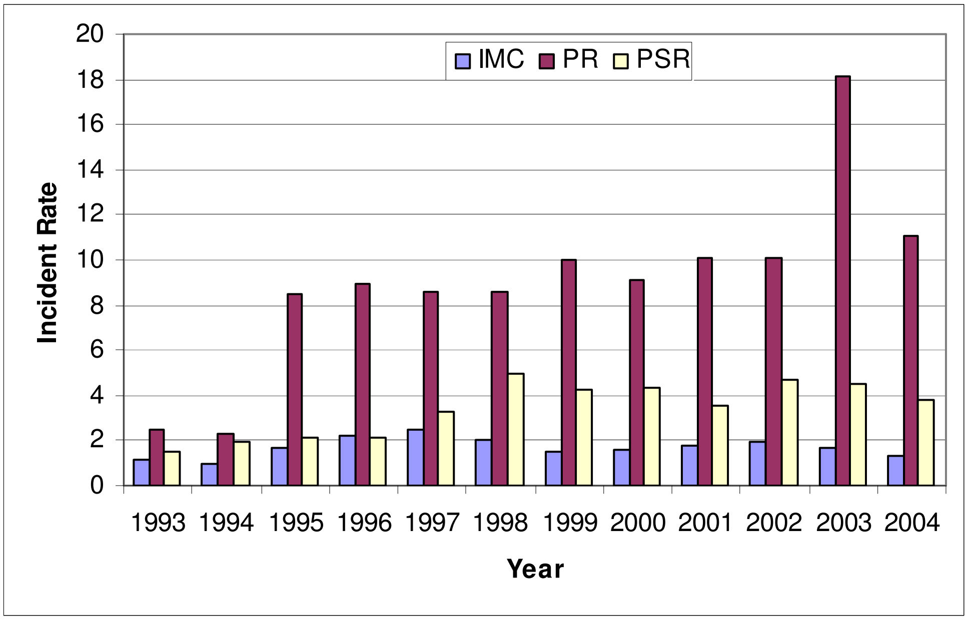


Figure 8. Yearly incident rate (No. of incidents/No. of facilities) of IMC, PR and PSR industries in Texas (Source: HSSES, 1993-2004)

Figure 8 shows yearly incident rate of IMC, PR and PSR industries in Texas. The rate of incidents in the Petroleum Refining industries is definitely an uptrend.

7.4. Incident Distribution by Incident Type

Table 5. Yearly distribution of events by type of incident for IMC, PR and PSR industries in Texas (Source: HSEES and U.S. Census Bureau, 2000-2004)

Year	No. Ind.	Fac-ility Type	Incident	Type of Incident											
				SS	SS Rate	ME	ME Rate	PU	PU Rate	PF	PF Rate	F&E	F&E Rate	Interr-uption Event	Comp-arison Event
2000	532	IMC	867	161	0.30	13	0.02	113	0.21	12	0.02	1	0.00	300	567
2001	512		904	155	0.30	35	0.07	158	0.31	19	0.04	7	0.01	374	530
2002	502		993	203	0.40	163	0.32	283	0.56	47	0.09	11	0.02	707	286
2003	489		841	200	0.41	108	0.22	174	0.36	51	0.10	11	0.02	544	297
2004	503		653	153	0.30	85	0.17	170	0.34	42	0.08	9	0.02	459	194
Total	2538		4258	872	0.34	404	0.16	898	0.35	171	0.07	39	0.02	2384	1874
2000	51	PR	463	47	0.92	8	0.16	99	1.94	5	0.10	2	0.04	161	302
2001	52		523	68	1.31	12	0.23	98	1.88	12	0.23	3	0.06	193	330
2002	64		643	135	2.11	53	0.83	258	4.03	54	0.84	9	0.14	509	134
2003	41		743	170	4.15	117	2.85	271	6.61	47	1.15	8	0.20	613	130
2004	54		595	101	1.87	86	1.59	271	5.02	37	0.69	3	0.06	498	97
Total	262		2967	521	1.99	276	1.05	997	3.81	155	0.59	25	0.10	1974	993
2000	89	PSR	384	40	0.45	16	0.18	75	0.84	2	0.02	1	0.01	134	250
2001	94		334	45	0.48	14	0.15	51	0.54	3	0.03	5	0.05	118	216
2002	102		480	108	1.06	84	0.82	156	1.53	18	0.18	5	0.05	371	109
2003	108		487	124	1.15	78	0.72	138	1.28	23	0.21	3	0.03	366	121
2004	91		346	93	1.02	54	0.59	87	0.96	26	0.29	2	0.02	262	84
Total	484		2031	410	0.85	246	0.51	507	1.05	72	0.15	16	0.03	1251	780

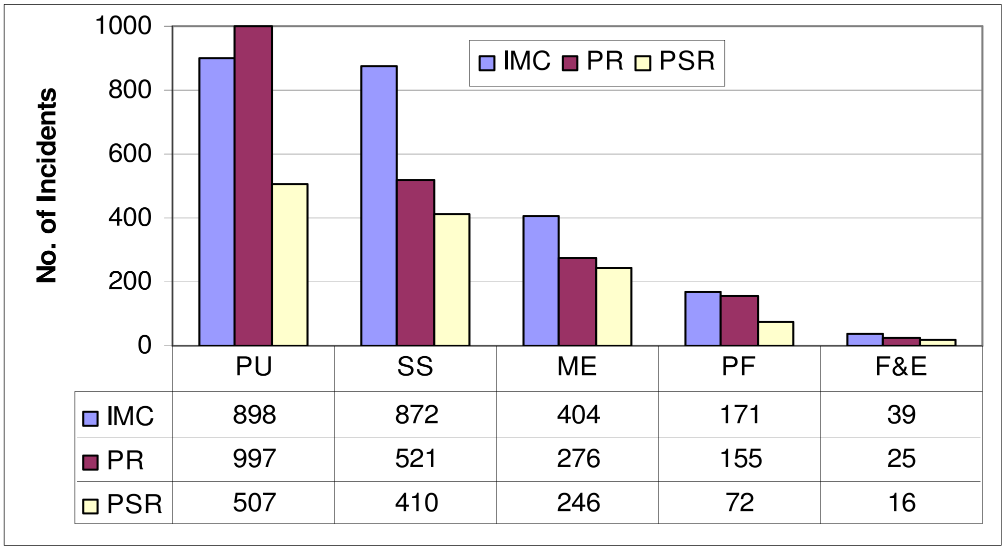


Figure 9. Distribution of process interruption events for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 9 represents what types of interruption events occurred in IMC, PR and PSR industries in Texas during 2000-2004. Process Upset events are higher in all three industries than any other type of events which is shown in the table 5. Startup/Shutdown events are the second most common interruption events followed by Maintenance, Power Failure, and Fire and Explosion events in IMC, PR and PSR industries. Maintenance and Startup/Shutdown are often considered planned work; however, large number of the incidents still occurred during these times. Maintenance and Startup/Shutdown events mentioned here include both planned and unplanned work.

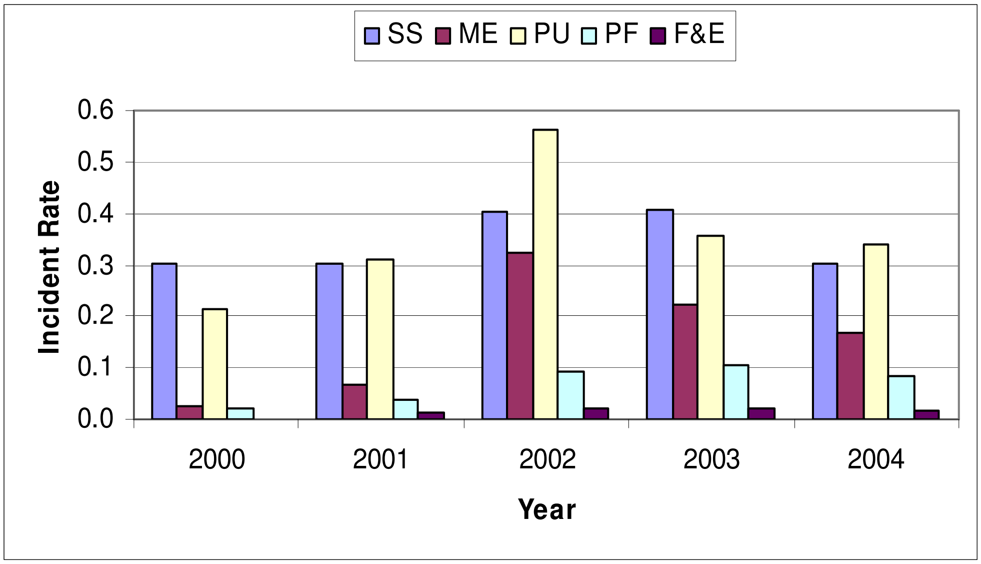


Figure 10. Yearly rate (No. of Incident/No. of facility) of incident in IMC industries in Texas (Source: HSEES, 2000-2004)

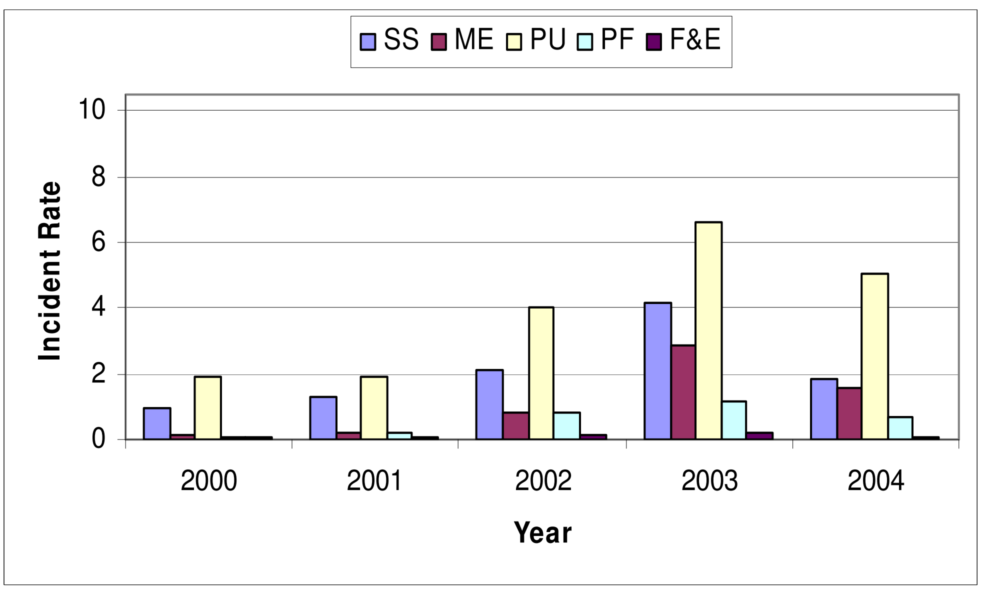


Figure 11. Yearly rate (No. of Incident/No. of facility) of incident in PR industries in Texas (Source: HSEES, 2000-2004)

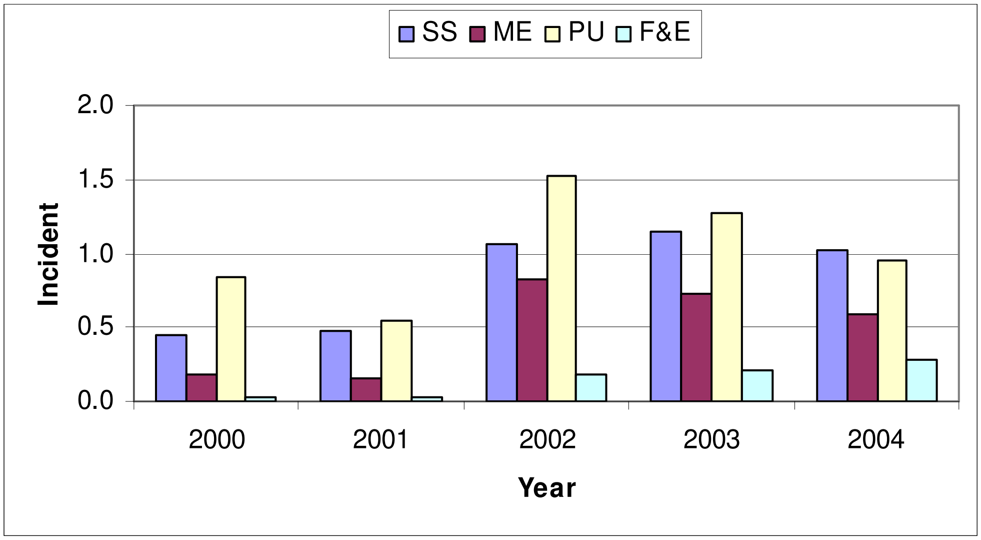


Figure 12. Yearly rate (No. of Incident/No. of facility) of incident in PSR industries in Texas (Source: HSEES, 2000-2004)

From Figures 10, 11, and 12, it can be concluded that the three types of facilities have similar incident trends. Process upset and startup/shutdown events show an upwards trend in all the three industries.

7.5. Incident Distribution by Time

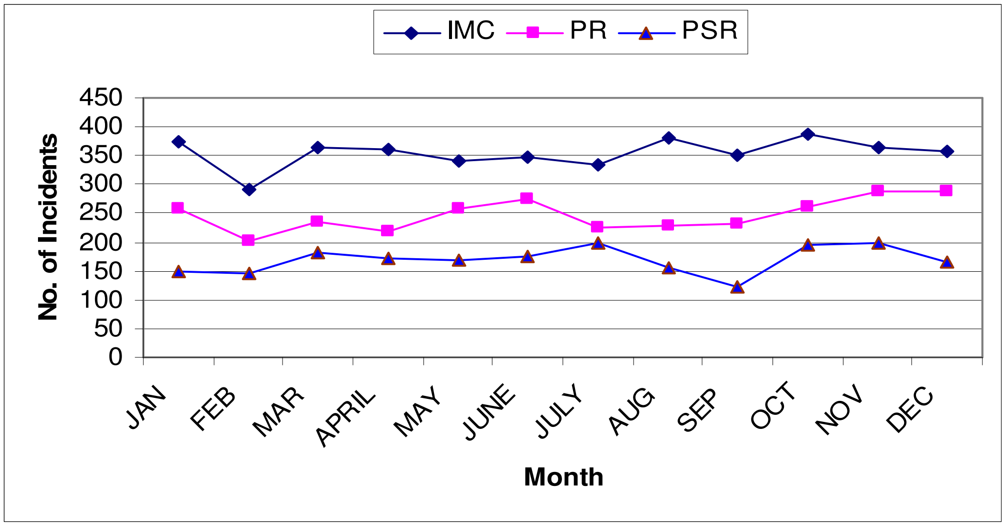


Figure 13. Incident distribution by month for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 13 shows the monthly distribution of manufacturing incidents in IMC, PR and PSR industries during 2000-2004. There is no significant trend in figure 13.

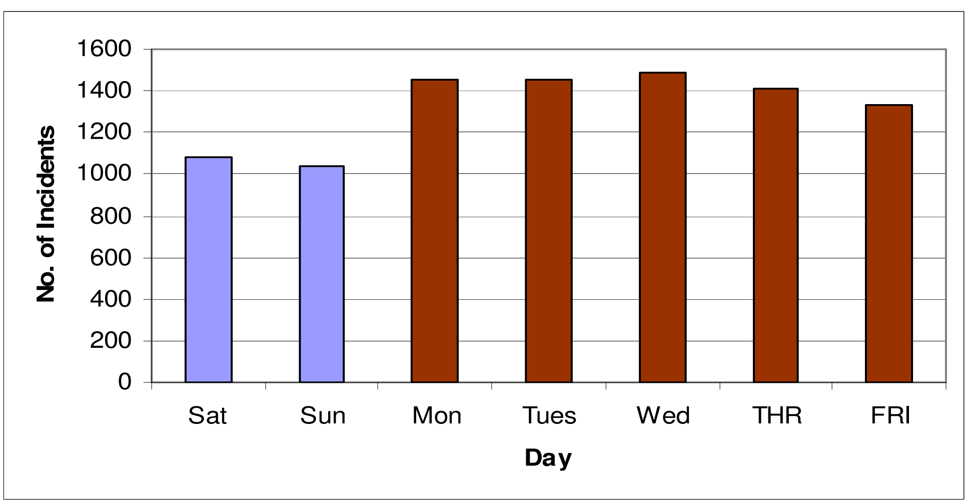


Figure 14. Distribution of incidents by day for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 14 represents the distribution of incidents by days of week for all the three industries in Texas during 2000-2004. This figure shows that the numbers of incidents are higher in weekdays compared to weekends. Plant activities are higher during the weekdays as well and account for more incidents.

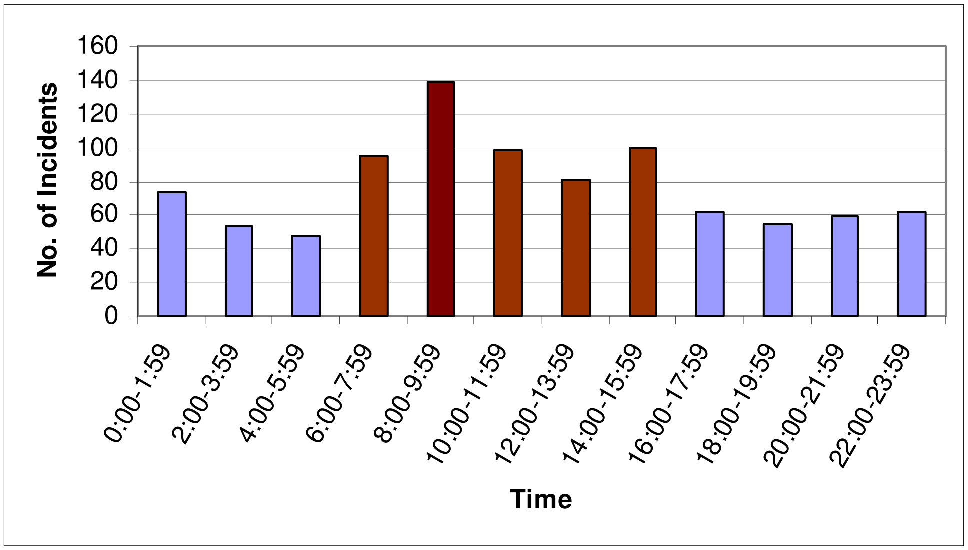


Figure 15. Distribution of maintenance events by time for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 15 represents the distribution of maintenance events by time of day. Maintenance events are high during 6-16 and peak during 8a.m-10a.m. Important jobs are probably started early in the morning, this could be the reason behind the peak incidents during 8a.m-10a.m.

7.6. Cause Analysis

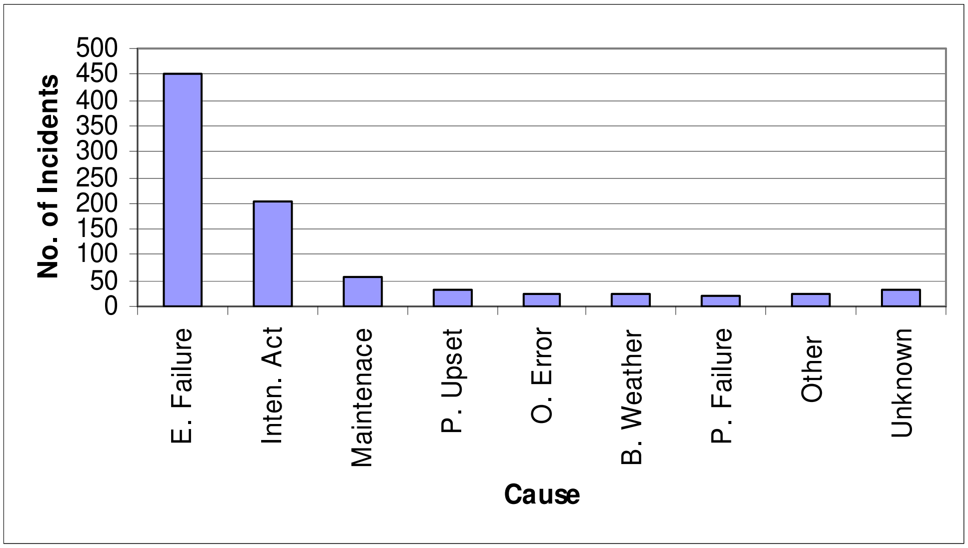


Figure 16. Distribution of startup/shutdown events by cause for Industrial and Miscellaneous Chemical Industries (IMC) in Texas (source: HSEES, 2000-2004)

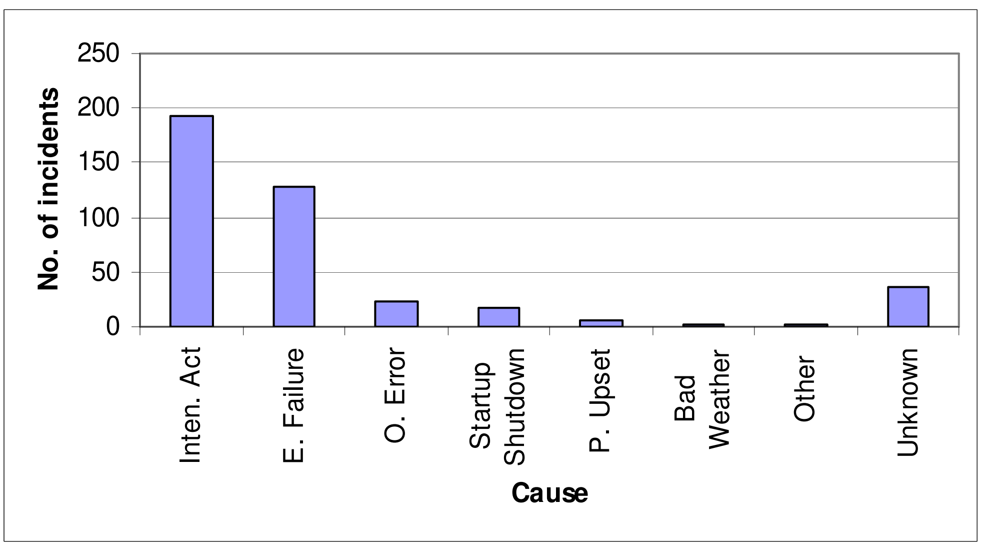


Figure 17. Distribution of maintenance events by cause for Industrial and Miscellaneous Chemical Industries (IMC) in Texas (source: HSEES, 2000-2004)

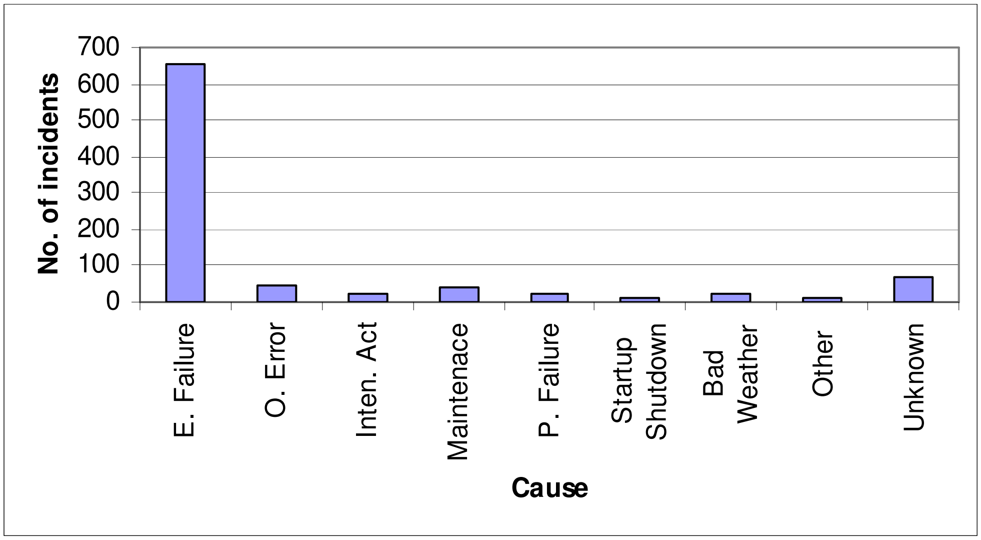


Figure 18. Distribution of process upset events by cause for Industrial and Miscellaneous Chemical Industries (IMC) in Texas (source: HSEES, 2000-2004)

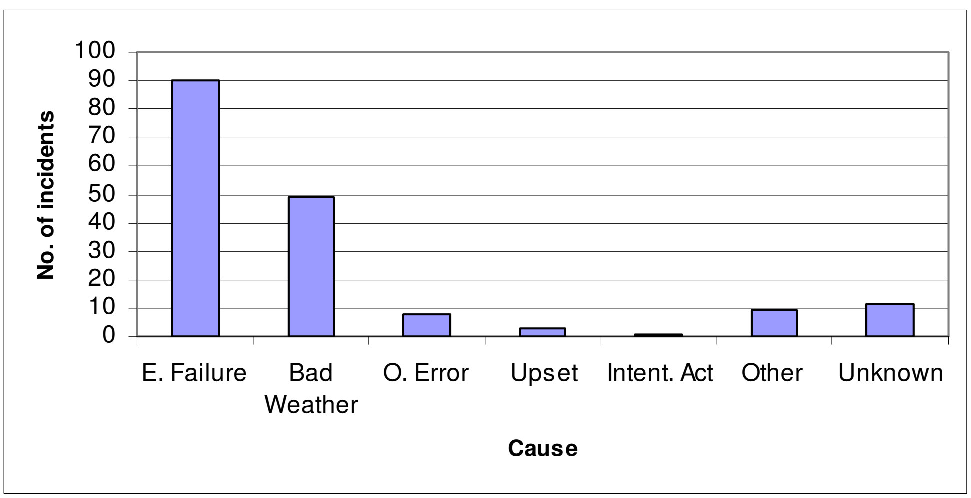


Figure 19. Distribution of power failure events by cause for Industrial and Miscellaneous Chemical Industries (IMC) in Texas (source: HSEES, 2000-2004)

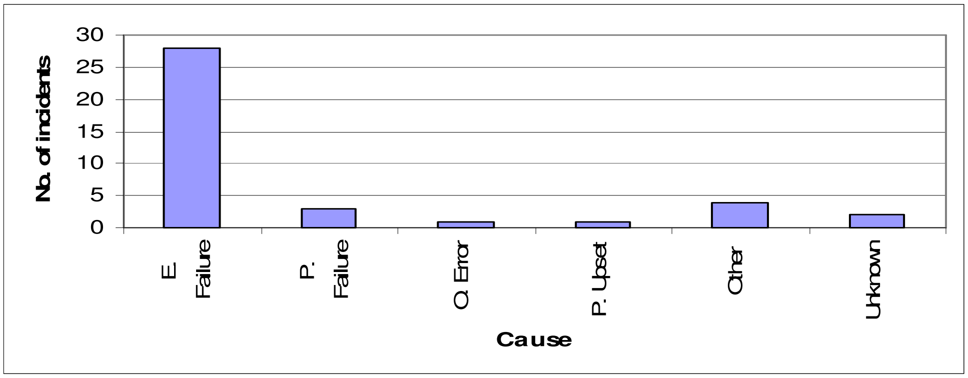


Figure 20. Distribution of fire and explosion events by cause for Industrial and Miscellaneous Chemical Industries (IMC) in Texas (source: HSEES, 2000-2004)

Figures 16-20 represent the causes of the interruption events in industrial and miscellaneous chemical (IMC) industries in Texas during 2000-2004. Figures show

- Equipment failure is the number one cause of incidents associated with:
  - Startup/Shutdown (52%)
  - Process Upset (73%)
  - Power Failure (53%)
  - Fire and Explosion (72%) and
  - Second most cause of Maintenance (32%)
- Intentional or illegal acts are the number one cause of
  - Maintenance Event(48%) and
  - second most cause of Startup/Shutdown (23%) incidents
- Operator Error is associated with few numbers of incidents:
  - Startup/Shutdown (3%),
  - Maintenance (6%),
  - Power Failure (5%), and
  - Process Upset (5%),
  - Fire and Explosion (3%)
- 29% of Power Failure incidents occurred due to bad weather (BW): second most frequent cause

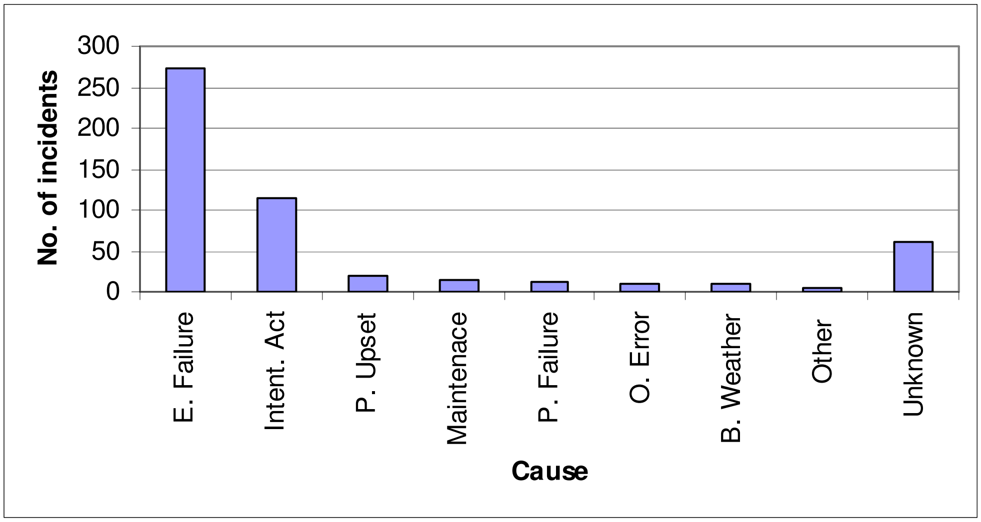


Figure 21. Distribution of startup/shutdown events by cause for Petroleum Refining Industries (PR) in Texas (source: HSEES, 2000-2004)

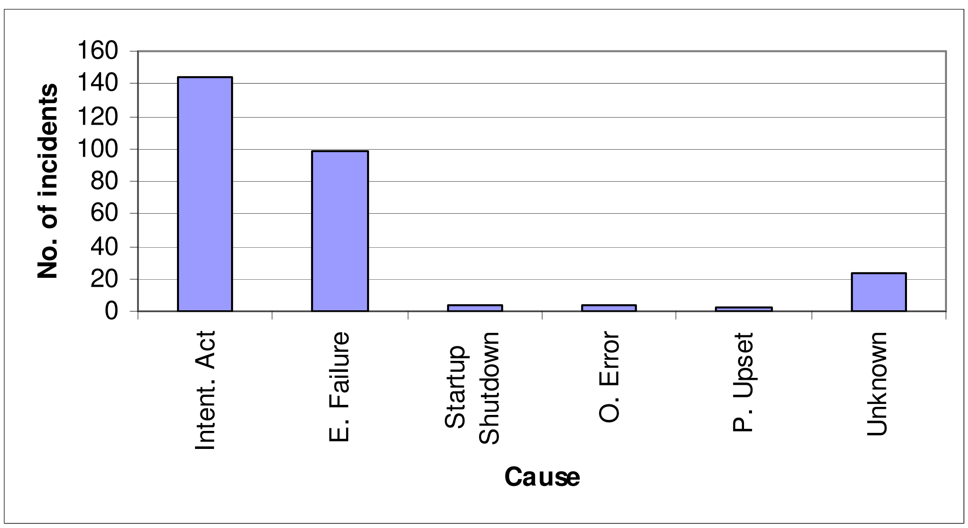


Figure 22. Distribution of maintenance events by cause for Petroleum Refining Industries (PR) in Texas (source: HSEES, 2000-2004)

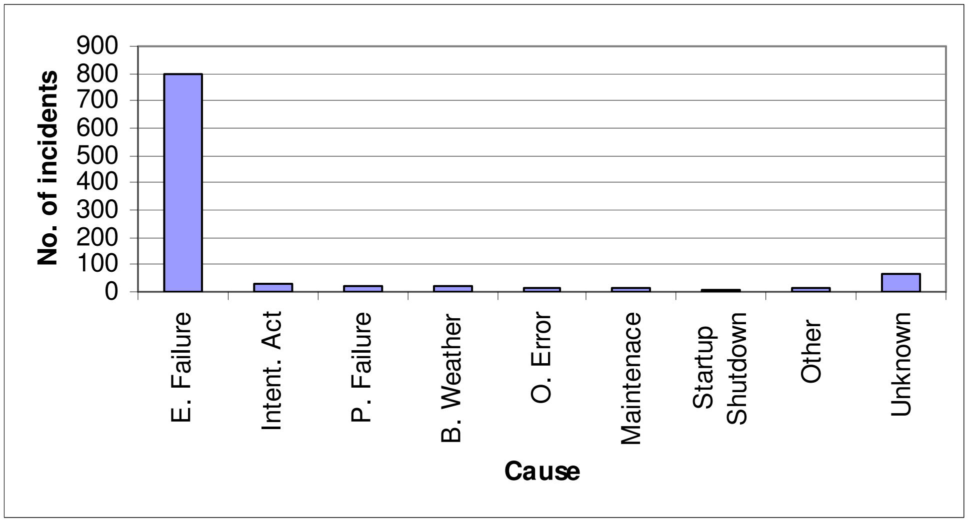


Figure 23. Distribution of process upset events by cause for Petroleum Refining Industry (PR) in Texas (source: HSEES, 2000-2004)

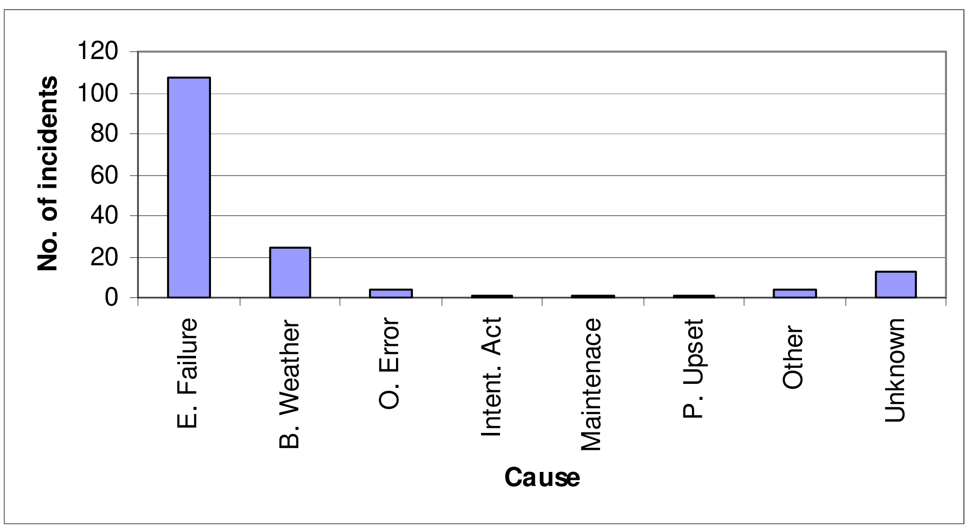


Figure 24. Distribution of power failure events by cause for Petroleum Refining Industries (PR) in Texas (source: HSEES, 2000-2004)

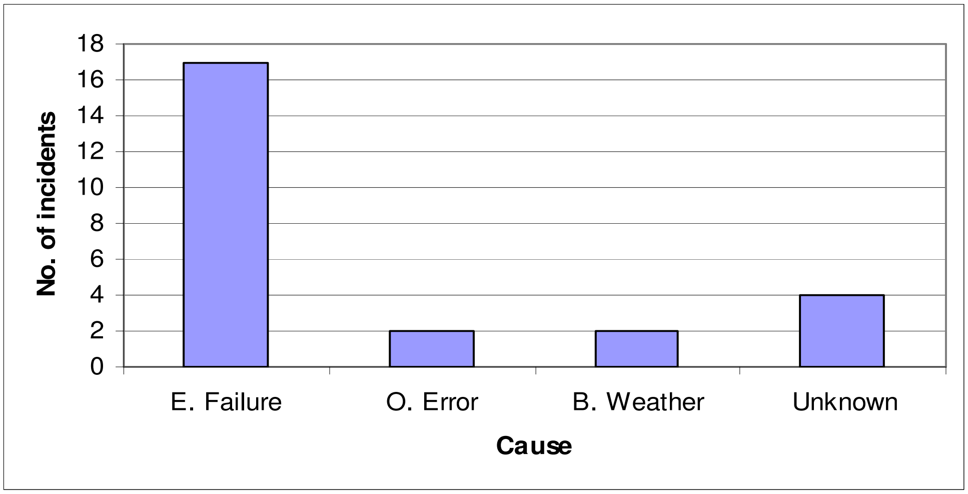


Figure 25. Distribution of fire and explosion events by cause for Petroleum Refining Industries (PR) in Texas (source: HSEES, 2000-2004)

Figures 21-25 represent the causes of the interruption events in Petroleum Refining (PR) industries in Texas during 2000-2004. Figures show

- Equipment failure is the number one cause of incidents associated with:
    - Startup/Shutdown (53%)
    - Process Upset (81%)
    - Power Failure (69%)
    - Fire and Explosion (68%) and
    - Second most cause of Maintenance (32%)
- Intentional or illegal acts are the number one cause of
    - Maintenance Event(52%) and
    - second most cause of Startup/Shutdown (22%) incidents

- Operator Error is associated with few numbers of incidents:
    - Startup/Shutdown (2%),
    - Maintenance (1%),
    - Power Failure (3%), and
    - Process Upset (2%),
    - Fire and Explosion (8%)
- 16% of Power Failure (PF) incidents occurred due to bad weather (BW): second most frequent cause.

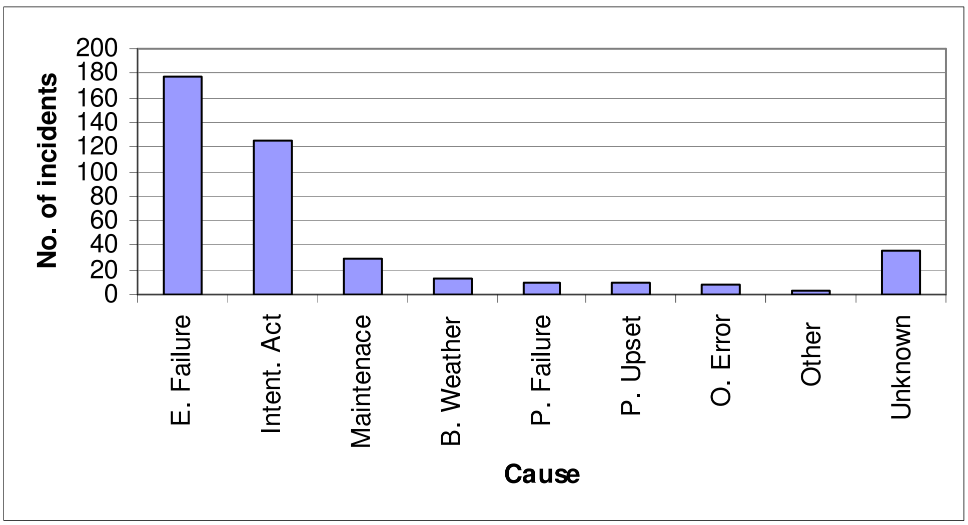


Figure 26. Distribution of startup/shutdown events by cause for Plastic, Synthetic and Resin (PSR) Industries in Texas (Source: HSEES, 2000-2004)

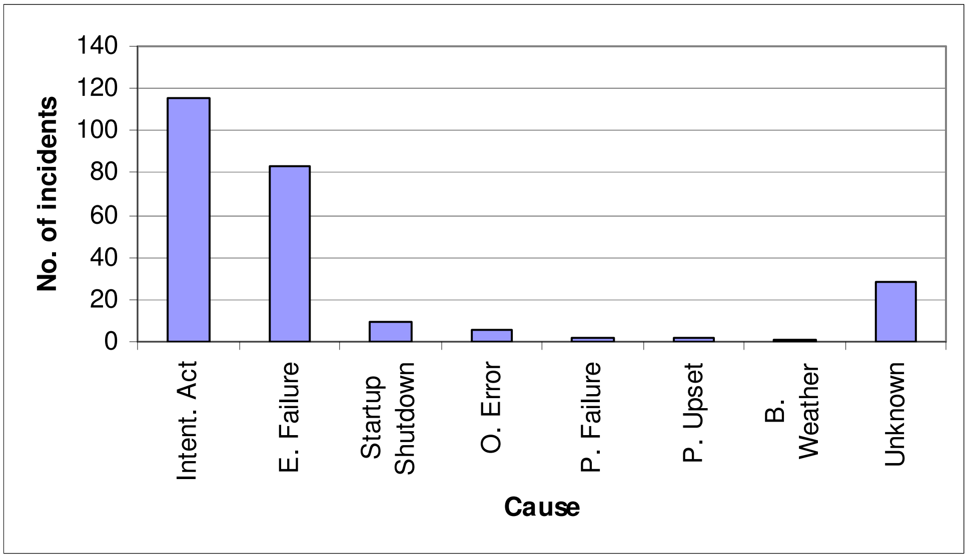


Figure 27. Distribution of maintenance events by cause for Plastic, Synthetic and Resin (PSR) Industries in Texas (Source: HSEES, 2000-2004)

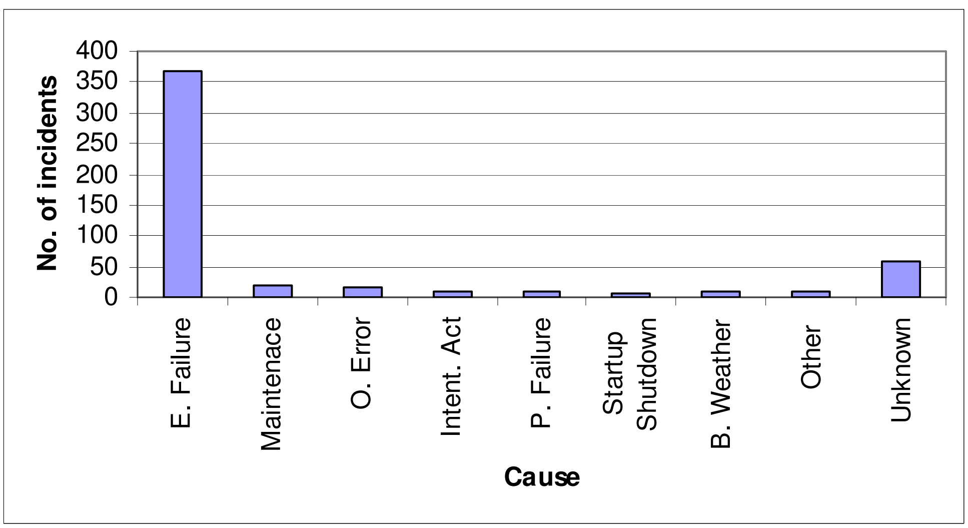


Figure 28. Distribution of process upset events by cause for Plastic, Synthetic and Resin (PSR) Industries in Texas (Source: HSEES, 2000-2004)

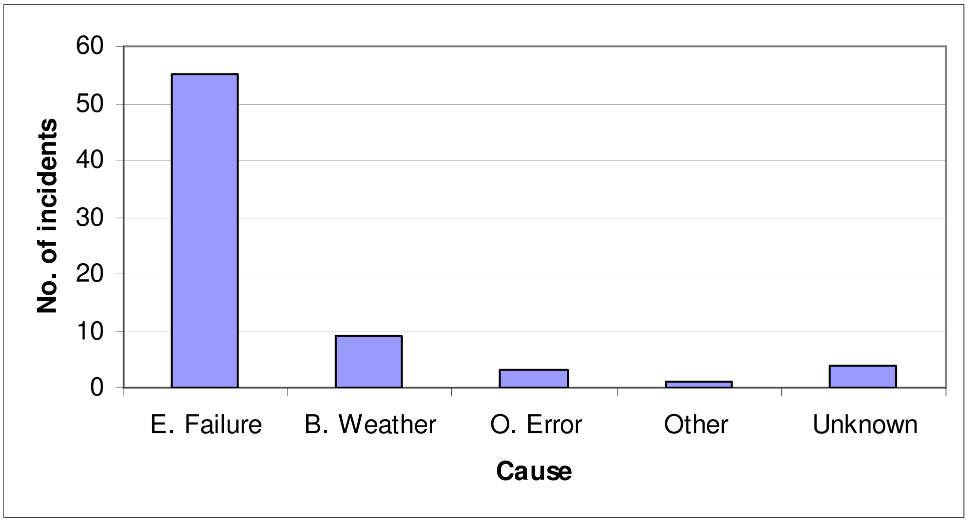


Figure 29. Distribution of power failure events by cause for Plastic, Synthetic and Resin (PSR) Industries in Texas (Source: HSEES, 2000-2004)

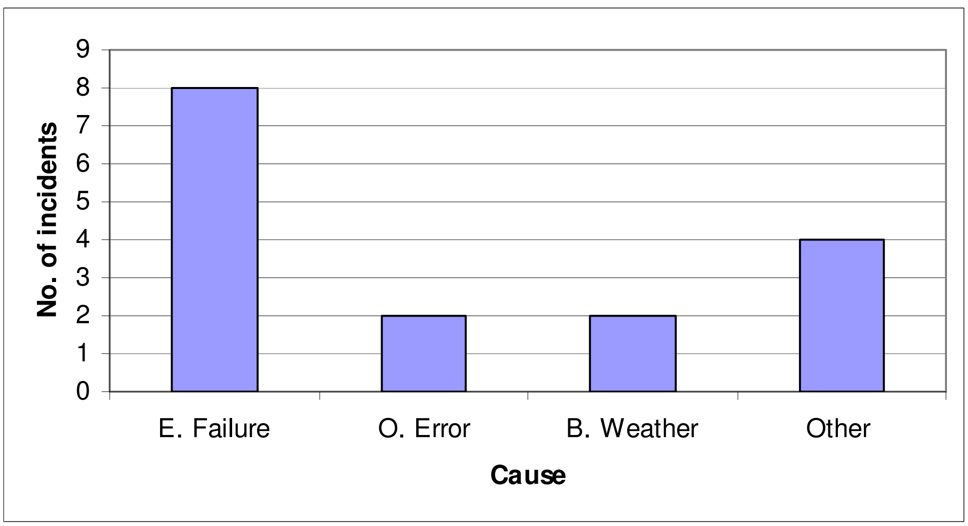
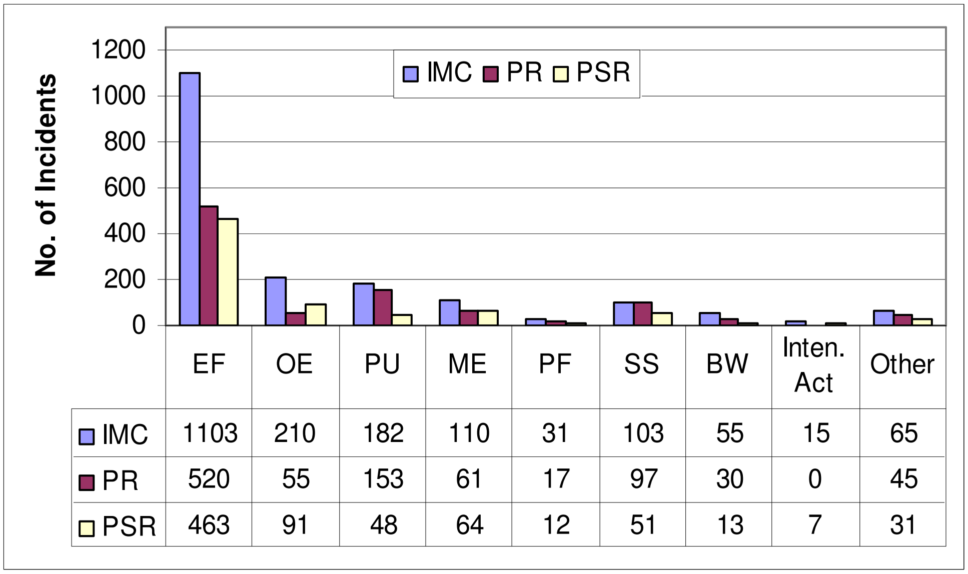


Figure 30. Distribution of fire and explosion events by cause for Plastic, Synthetic and Resin (PSR) Industries in Texas (Source: HSEES, 2000-2004)

Figures 26-30 represent the causes of the interruption events in Petroleum Refining (PR) industries in Texas during 2000-2004. Figures show

- Equipment failure is the number one cause of incidents associated with:
    - Startup/Shutdown (43%)
    - Process Upset (73%)
    - Power Failure (69%)
    - Fire and Explosion (76%) and
    - Second most cause of Maintenance (34%)
- Intentional or illegal acts are the number one cause of
    - Maintenance Event(47%) and
    - Second most cause of Startup/Shutdown (30%) incidents
- Operator Error is associated with few numbers of incidents:
    - Startup/Shutdown (2%),
    - Maintenance (2%),
    - Power Failure (4%), and
    - Process Upset (3%),
    - Fire and Explosion (13%)
- 13% of Power Failure (PF)incidents occurred due to bad weather (BW): second most frequent cause



	EF	OE	PU	ME	PF	SS	BW	Inten. Act	Other
IMC	1103	210	182	110	31	103	55	15	65
PR	520	55	153	61	17	97	30	0	45
PSR	463	91	48	64	12	51	13	7	31

Figure 31. Distribution of comparison events by cause for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 31 shows the causes of comparison events of IMC, PR and PSR industries during 2000-2004 in Texas. The contributing factors of the comparison events for the Industrial and Miscellaneous Chemical industries are:

- Equipment Failure (59%)
- Operator Error (11%)
- Process Upset (10%)
- Maintenance (6%)
- Startup/Shutdown (5%)
- Bad Weather (3%)
- Power Failure (2%)
- Intentional or Illegal act (1%)
- Others (3%)

The contributing factors of the comparison events for the Petroleum Refining industries are:

- Equipment Failure (52%)
- Operator Error (6%)
- Process Upset (15%)
- Maintenance (6%)
- Startup/Shutdown (10%)
- Power Failure (2%)
- Bad Weather (3%)
- Others (5%)

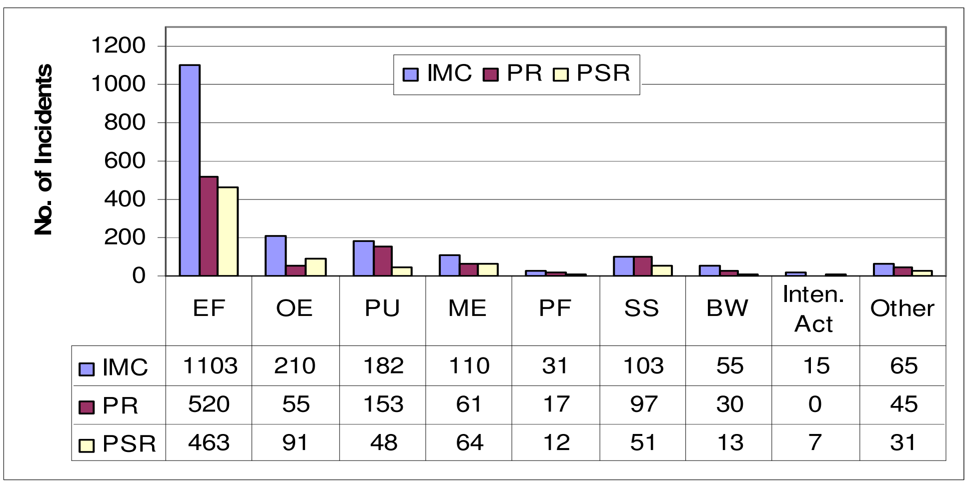
The contributing factors of the comparison events for the Plastic, Synthetic and Resin industries are:

- Equipment Failure (59%)
- Operator Error (12%)
- Process Upset (6%)
- Maintenance (8%)
- Startup/Shutdown (7%)
- Bad Weather (2%)
- Power Failure (2%)
- Intentional or Illegal act (1%)
- Others (4%)

Cause analysis shows that there are some common contributing factors of the incidents in the three industries. Equipment failure is the number one cause of process SS, PU, PF, and F&E events in all the three industries. Intentional or illegal acts are the number one cause of maintenance incidents in the three industries. This is because when people want to perform maintenance, it is not human error or equipment failure that causes the release.

They are fully aware that their actions will cause a release above permitted quantities (so it is intentional) and many times report them in advance to get a waiver (because they have a waiver it is not illegal). After equipment failure, bad weather (BW) is the second most contributing factor for power failure (PF) events for all the three industries. Comparison events are more frequently caused by operator error and less frequently caused by intentional or illegal acts. Whereas, interruption events are more frequently caused by intentional or illegal acts and less frequently caused by operator errors.

7.7. Area/Equipment Distribution



	EF	OE	PU	ME	PF	SS	BW	Inten. Act	Other
IMC	1103	210	182	110	31	103	55	15	65
PR	520	55	153	61	17	97	30	0	45
PSR	463	91	48	64	12	51	13	7	31

Figure 32. Distribution of incidents by area/equipment for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 32 represents Areas/Equipment involved during the incidents for three industries. It can be concluded that the Area/Equipment involved in the Industrial and Miscellaneous Chemical industries are:

- Ancillary process equipment (APE) (47%)
- Process vessel (PV) (24%)
- Pipe (16%)
- Storage above the ground (SAG) (6%)
- Material handling area (MHA) (2%)
- Dump/Waste area (DA/WA) (1%)
- Incinerator (INCIN) (2%)
- Other (2%)

Area/Equipment involved in the Petroleum Refining industries is:

- Ancillary process equipment (65%)
- Process vessel (19%)
- Pipe (10%)
- Storage above the ground (4%)
- Material handling area (1%)
- Incinerator (1%)
- Other (1%)

Area/Equipment involved in the Plastic, Synthetic and Resin industries are:

- Ancillary process equipment (45%)
- Process vessel (34%)
- Pipe (14%)
- Storage above the ground (4%)
- Material handling area (1%)
- Other (2%)

7.8. Chemical Distribution

Table 6. Cumulative data by year for IMC, PR and PSR industries in Texas (source: HSEES, 2000-2004)

Year	Facility Type	Incidents	No. of Substances	No. of Victims	No. of Death	No. incidents with Victims	
						No.	% of incidents with victims
2000	IMC	867	877	20	0	6	0.69%
2001		904	909	67	0	9	1.00%
2002		993	999	19	0	4	0.40%
2003		841	859	16	1	5	0.59%
2004		653	669	8	1	3	0.46%
Total		4258	4313	130	2	27	0.63%
2000	PR	463	464	10	0	2	0.43%
2001		523	535	28	0	4	0.76%
2002		643	643	1	0	1	0.16%
2003		743	743	17	0	1	0.13%
2004		595	596	12	0	1	0.17%
Total		2967	2981	68	0	9	0.30%
2000	PSR	384	395	92	1	3	0.78%
2001		334	340	7	0	10	2.99%
2002		480	483	8	0	2	0.42%
2003		487	489	1	0	1	0.21%
2004		346	348	2	0	1	0.29%
Total		2031	2055	110	1	17	0.84%

Table 6 shows the number of substances released, number of victims, number of fatalities and number of events with victims associated with the incident for IMC, PR and PSR industries during 2000-2004.

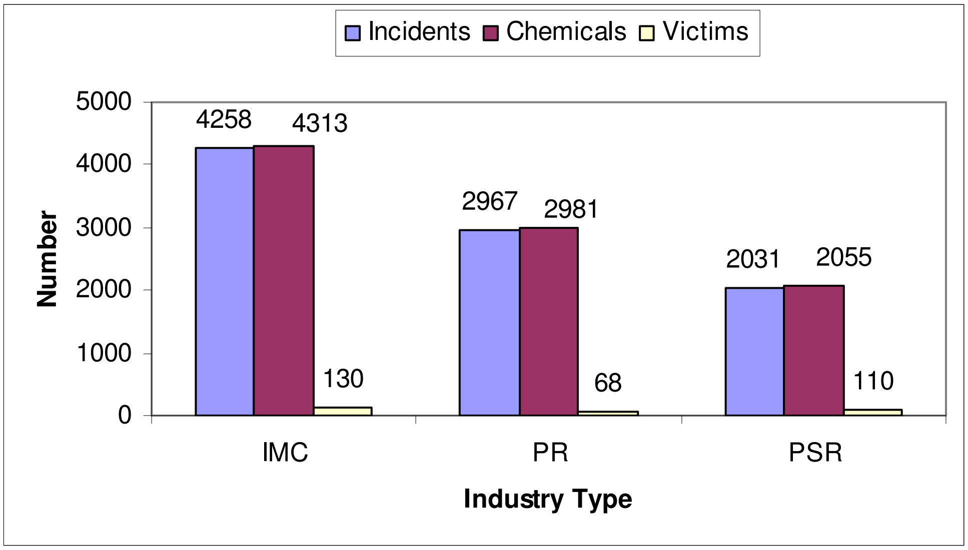


Figure 33. Distribution of events by substances released, victims for IMC, PR and PSR manufacturing industries incidents in Texas (Source: HSEES, 2000-2004)

Figure 33 represents the number of substances released; victims associated with incidents for the IMC, PR and PSR industries during 2002-2004 in Texas. This figure shows that the number of chemicals released is greater than the number of incidents because one incident could have more than one chemicals released.

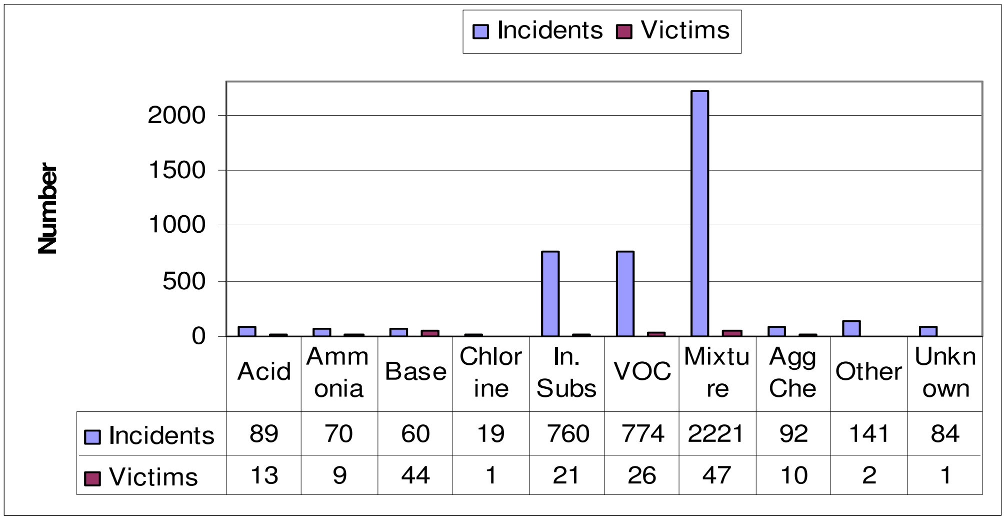


Figure 34. Distribution of events by substance category and associated victims for Industrial and Miscellaneous Chemical (IMC) industries in Texas (Source: HSEES, 2000-2004)

The most frequently released substances for IMC industries are:

- Mixtures 52%
- Inorganic substances 18%
- Volatile organic compounds 18%
- Agricultural chemical and pesticide 2%
- Acid 2%
- Ammonia 2%
- Bases 1%
- Other 3%
- Unknown 2%

Figure 34 represents incidents associated with mixtures have the highest number of victims.

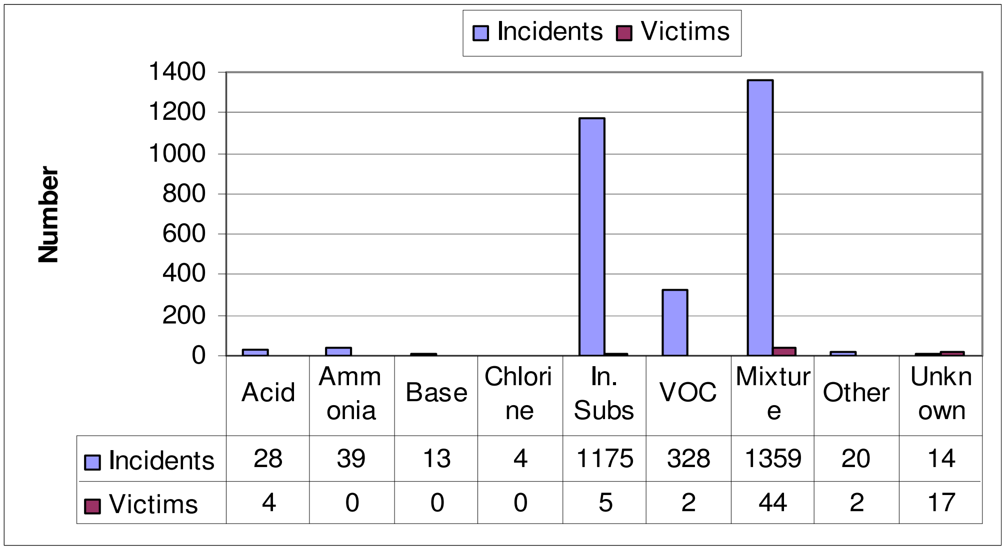
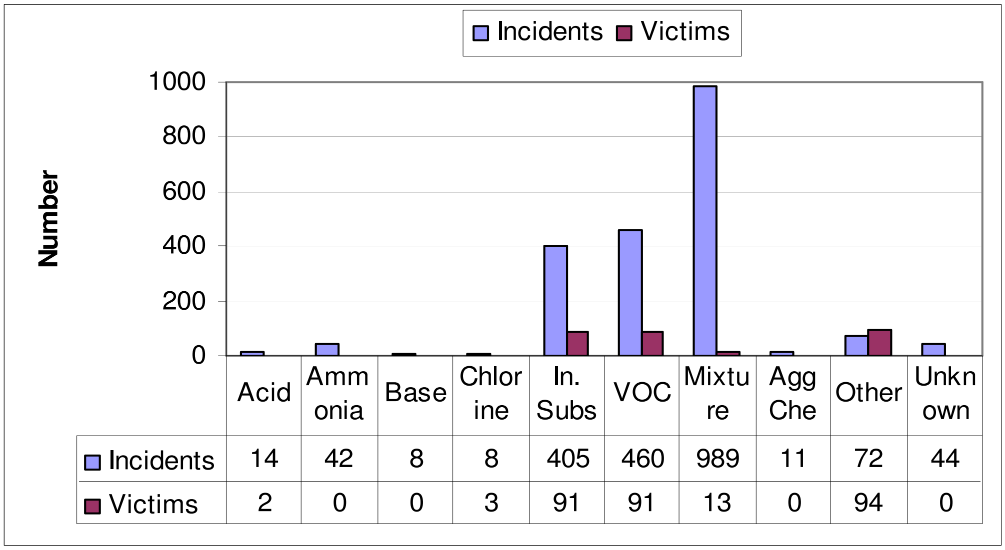


Figure 35. Distribution of events by substance category and associated victims for Petroleum Refining (PR) industries in Texas (Source: HSEES, 2000-2004)

The most frequently released substances for PR industries are:

- Mixtures 46%
- Inorganic substances 39%
- Volatile organic compounds 11%
- Acid 1%
- Ammonia 1.31%
- Other 0.67%
- Unknown 0.47%

Figure 35 represents incidents associated with mixtures have the highest number of victims.



	Acid	Ammonia	Base	Chlorine	In. Subs	VOC	Mixture	Agg Che	Other	Unknown
Incidents	14	42	8	8	405	460	989	11	72	44
Victims	2	0	0	3	91	91	13	0	94	0

Figure 36. Distribution of events by substance category and associated victims for Plastic, Synthetic and Resin (PSR) industries in Texas (Source: HSEES, 2000-2004)

The most frequently released substances for PSR industries are:

- Mixtures 48%
- Inorganic substances 20%
- Volatile organic compounds 22%
- Ammonia 2%
- Agricultural chemical and pesticide 1%
- Acid 1%
- Base 0.4%
- Chlorine 0.4%
- Other 4%
- Unknown 2%

Figure 36 represents incidents associated with other chemicals, VOC and inorganic substances have the highest number of victims.

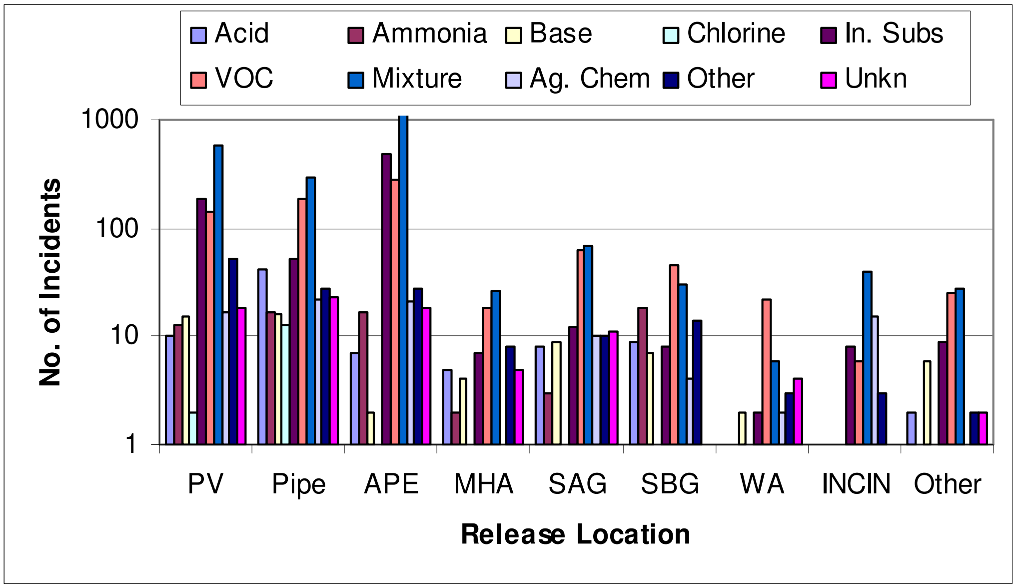


Figure 37. Distribution of events by release location of different chemicals for Industrial and Miscellaneous Chemical Industries in Texas. (Source: HSEES, 2000-2004)

Figure 37 represents the location of the released chemicals for the IMC industries during 2000-2004 in Texas. Percentage of different chemicals released associated with the percentage of the release locations given below:

- Acid (2%): Pipe 47%, process vessel (PV) 11%, storage below the ground (SBG) 10%, ancillary process equipment (APE) 8%, storage above the ground (SAG) 9%, material handling area (MHA) 6%, other 2%
- Ammonia (2%): SBG 26%, APE 24%, Pipe 24%, PV 19%, SAG 4%, MHA 3%
- Base (1%): Pipe 27%, PV 25% , SAG 15%, SBG 12%, Other 10%, MHA 7%
- Inorganic Substances (18%): APE 63%, PV 25%, pipe 7%, SAG 2%, SBG 1%
- Volatile organic compound (VOC) (18%): APE 35%, Pipe 24%, PV 19%, SAG 8%, SBG 6%,WA 3%
- Mixture (52%): APE 52%, PV 26%, Pipe 13%, SAG 3%, SBG 1%, MHA 1%
- Agricultural chemical and pesticide (Ag. Chem.) 2% : APE 23%, Pipe 24%, PV 18%, Incinerator 16%, SAG 11%
- Chlorine (0.44% : Pipe 68%, PV 11%, APE 5%, MHA 5%, SBG 5%

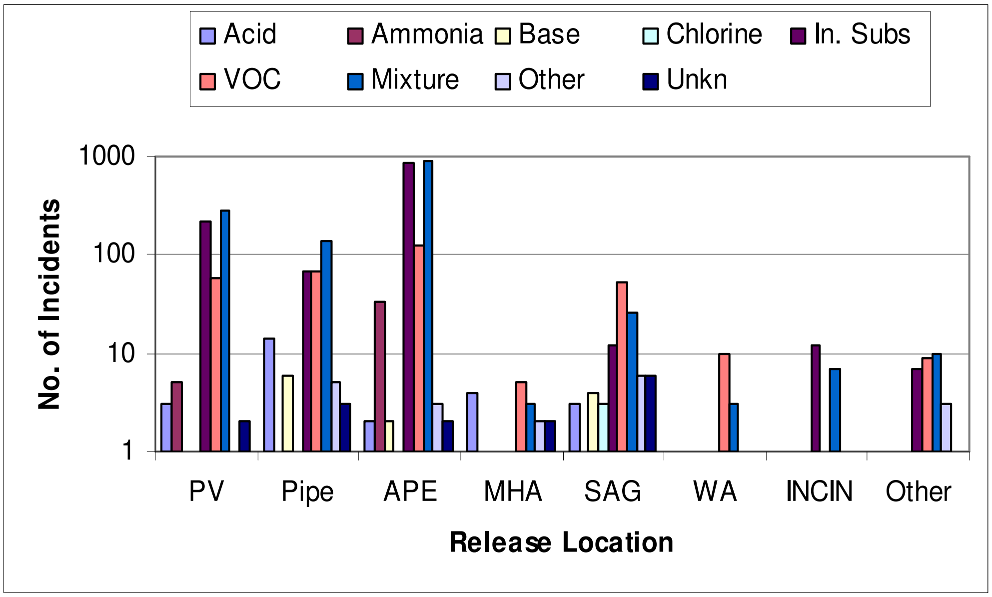


Figure 38. Distribution of events by release location of different chemicals for Petroleum and Refining (PR) industries in Texas (Source: HSEES, 2000-2004)

Figure 38 represents the location of the released chemicals for the PR industries during 2000-2004 in Texas. Percentage of different chemicals released associated with the percentage of the release locations given below:

- Mixture (46%): APE 66%, PV 20%, Pipe 10%, SAG 2%
- Inorganic substances (39%): APE 73%, PV 19%, Pipe 6%, SAG 1%,
- VOC (11%): APE 73%, Pipe 20%, PV18%, SAG 16%, WA 3%
- Ammonia (1.31%): APE 85%, PV 13%, Pipe 3%
- Acid (1%): Pipe 50%, MHA 14%, PV 11%, SAG 11%, APE 7%
- Base (0.44%): Pipe 46%, SAG 31%, , APE 15%, PV 8%
- Chlorine (0.13%): SAG 75%, Pipe 25%
- Other (47%): SAG 30%, Pipe 25%, APE 15%, Pipe 10%, PV 5%

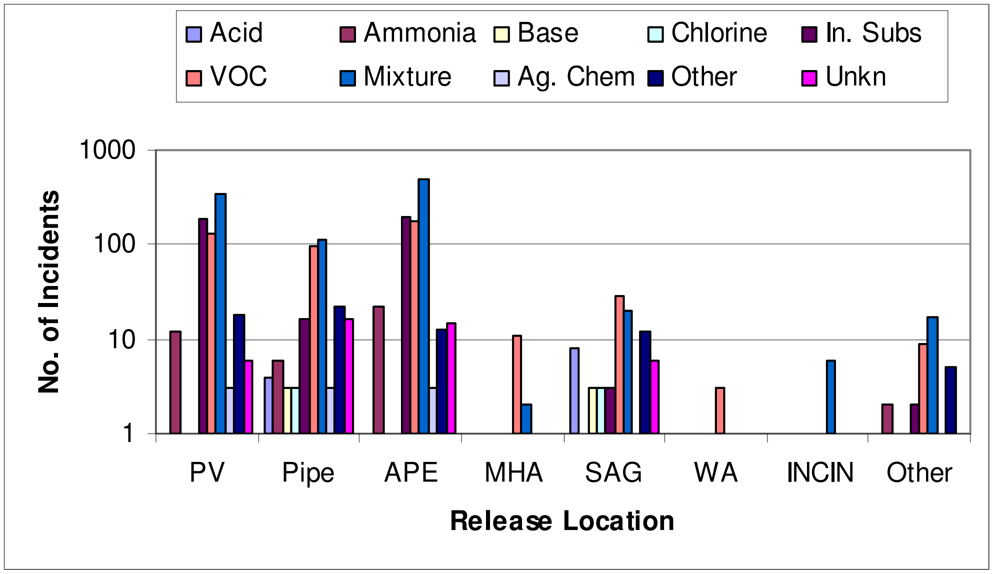


Figure 39. Distribution of events by release location of different chemicals for Plastic, Synthetic and Resin industries in Texas (Source: HSEES, 2000-2004)

Figure 39 represents the location of the released chemicals for the Plastic, Synthetic and Resin industries during 2000-2004 in Texas. Percentage of different chemicals released associated with the percentage of the release locations given below:

- Mixture (48%): APE 50%, PV 34%, Pipe 11%, SAG 2%
- VOC (23%): APE 39%, PV 28%, Pipe 21%, MHA 2%
- Inorganic Substances (20%): APE 48%, PV 46%, Pipe 4%
- Other (4%): Pipe 31%, PV 25%, APE 18%, SAG 17%, Other 7%
- Unknown (2%): Pipe 36%, APE 34%, PV 14%, SAG 14%, WA 2%
- Ammonia (2%): APE 52%, PV 29%, Pipe 14%, Other 5%, SAG 2%
- Acid (1%): SAG 57%, Pipe 29%, PV 7%, MHA 7%
- Base (0.4%): Pipe 38%, SAG 38%, APE 13%
- Chlorine (0.4%): Pipe 38%, SAG 38%, APE 13%, WA 13%, PV 13%

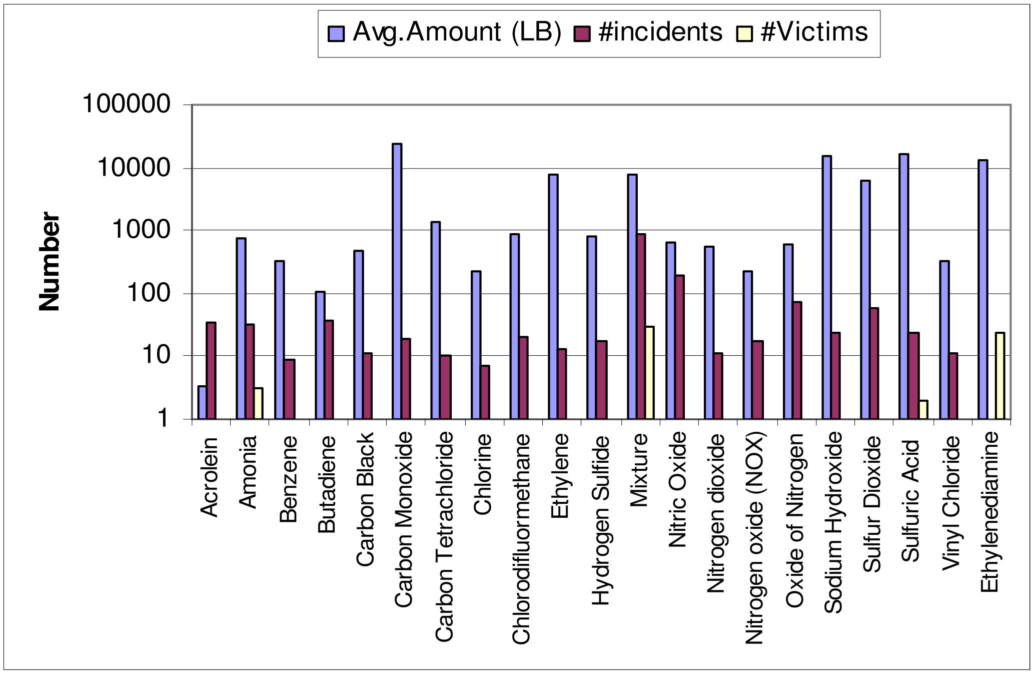


Figure 40. Distribution of most chemical release by substances name and associated release amount, victims in the IMC industries in Texas (Source: HSEES, 2000-2001)

From Figure 40 it can be concluded that for IMC industries in Texas

- Chemicals released with the highest amounts are CO, Ethylene, mixture, NaOH, Sulfuric acid , sulfur dioxide, CCl4, hydrogen sulfide, and ethylenediamine
- Victims associated with chemicals: ammonia, mixture, H_2S0_4, and ethylenediamine

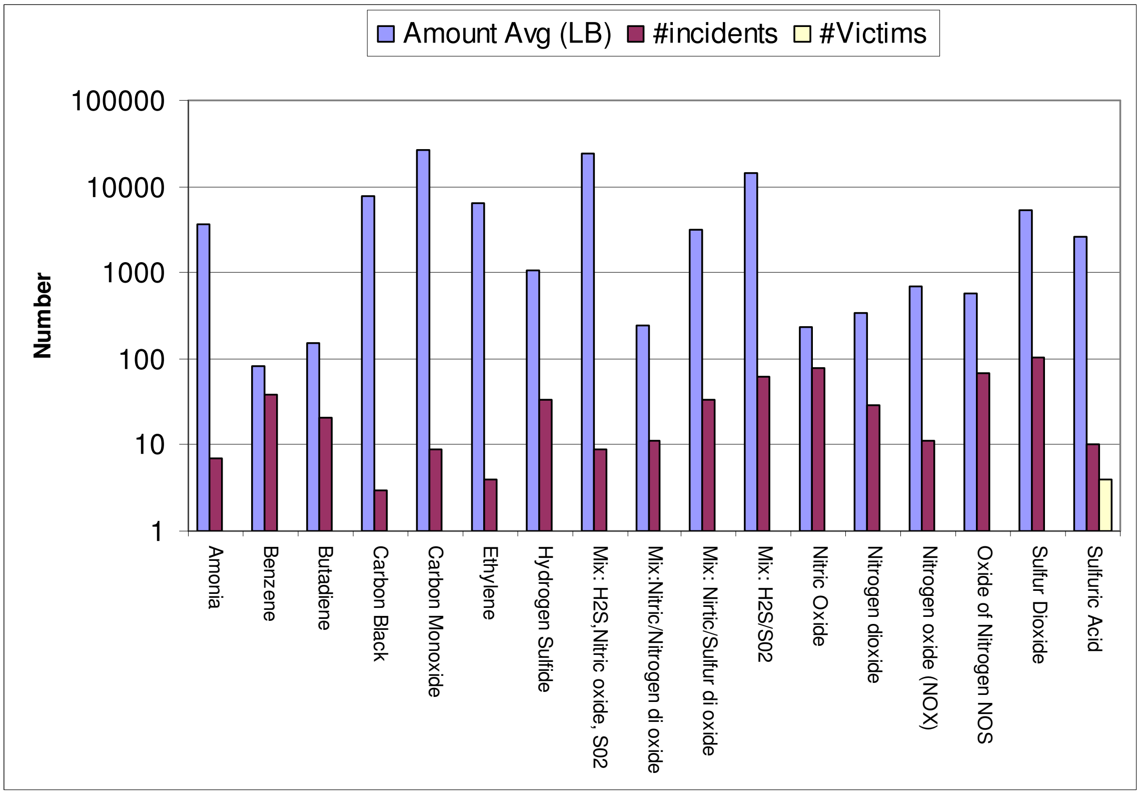


Figure 41. Distribution of most chemical release by substances name and associated release amount, victims in the PR industries in Texas (Source: HSEES, 2000-2001)

Figure 41 represents distribution of most chemical releases by substance name and associated release amount, victims for the PR industries in Texas during 2000-2002. The highest amounts of chemicals released are Ammonia, CO, Carbon Black, Ethylene, Mixture: H_2S/Nitric oxide/$S0_2$, Mixture: $H_2S/S0_2$, Sulfuric Acid, Sulfur dioxide, Hydrogen sulfide, and Nitrogen oxide (NOX). Sulfuric acid associated with the largest number of victims.

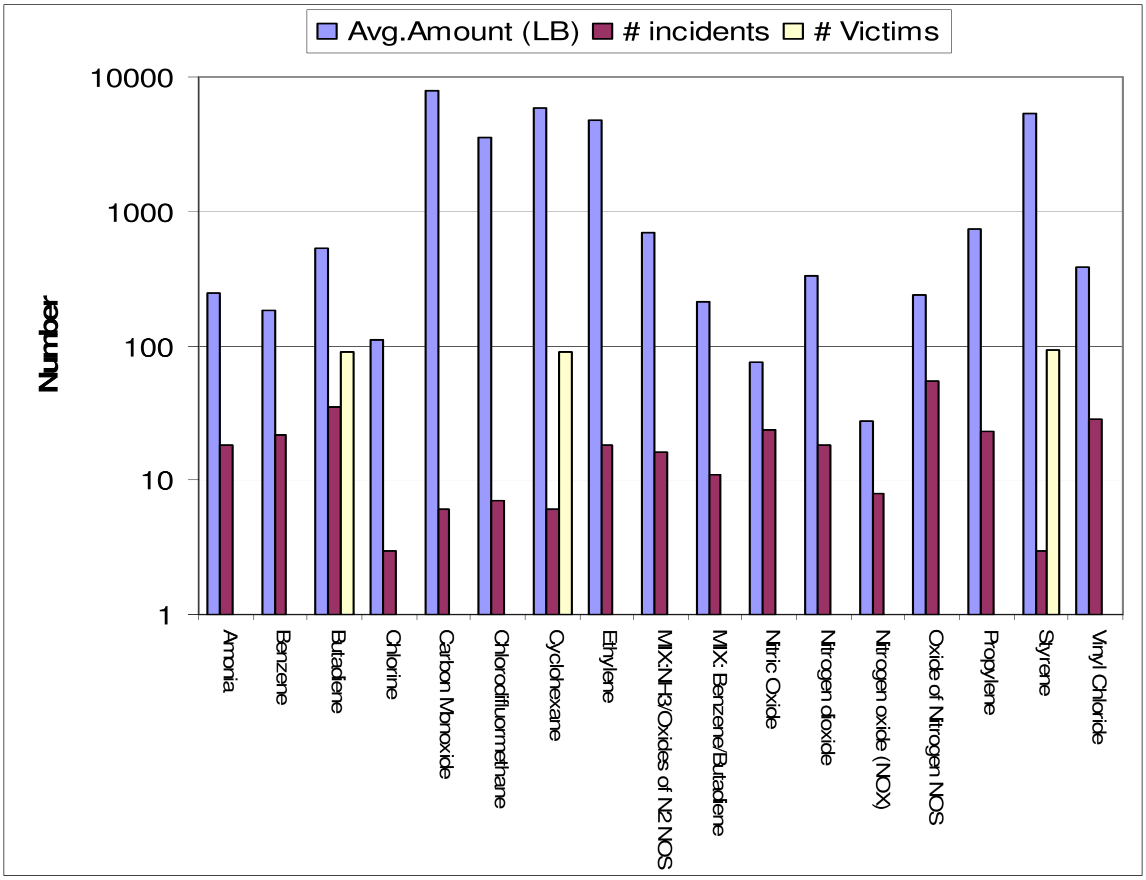


Figure 42. Distribution of most chemical release by substance name and associated release amount, victims in the PSR industries in Texas (Source: HSEES, 2000-2001)

From Figure 42 it can be concluded for PSR industries in Texas that

- Chemicals released with highest amounts: CO, Styrene, Vinyl Chloride, Cyclohexane, Ethylene, Propylene, Butadiene, Nitrogen dioxide, and Mixture: NH_3/Oxides of N_2 NOS
- Victims associated with chemicals: Styrene, Butadiene, Cyclohexane, and Chlorine

There are not many victims associated with those released chemicals, but the release amounts are high. This could have an adverse effect on the environment.

7.9. Victim Distribution

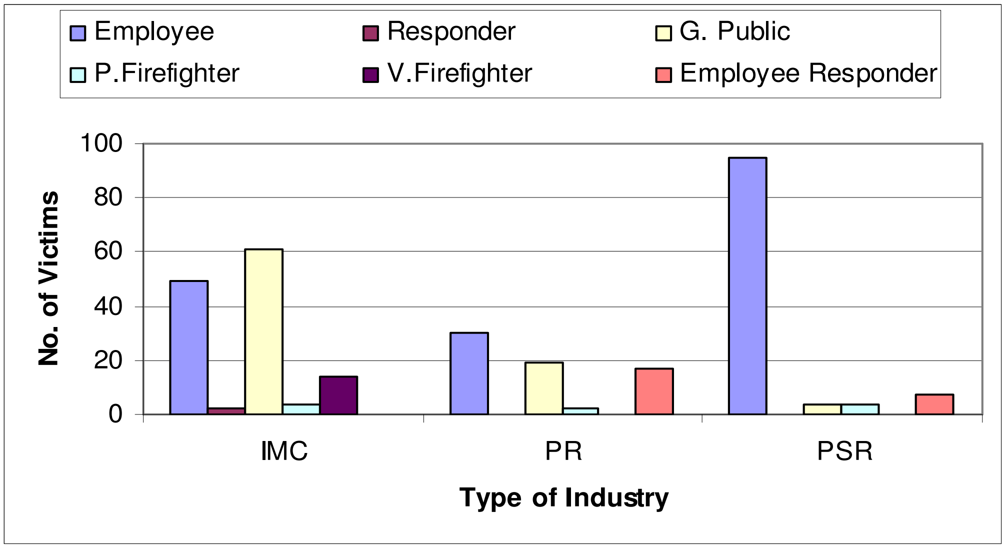


Figure 43. Distribution of victims by population group in IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Figure 43 represents distribution of victims, by population group for the IMC, PR and PSR industries in Texas during 200-2004.

Type of victims for IMC, PR and PSR industries are given below:

- IMC: Employee 38%, General public 47%, Volunteer firefighter 11%, Professional firefighter 3%, Responder 1%
- PR: Employee 44%, General public 28%, Employee is the member of the company response team 25%, Professional firefighter 3%
- PSR: Employee 86%, General public 4%, Employee is the member of the company response team 6%, , Professional firefighter 4%

Figure 43 shows the employees and the general public (G. public) are the most affected victims in those three industries.

7.10. Injury Distribution

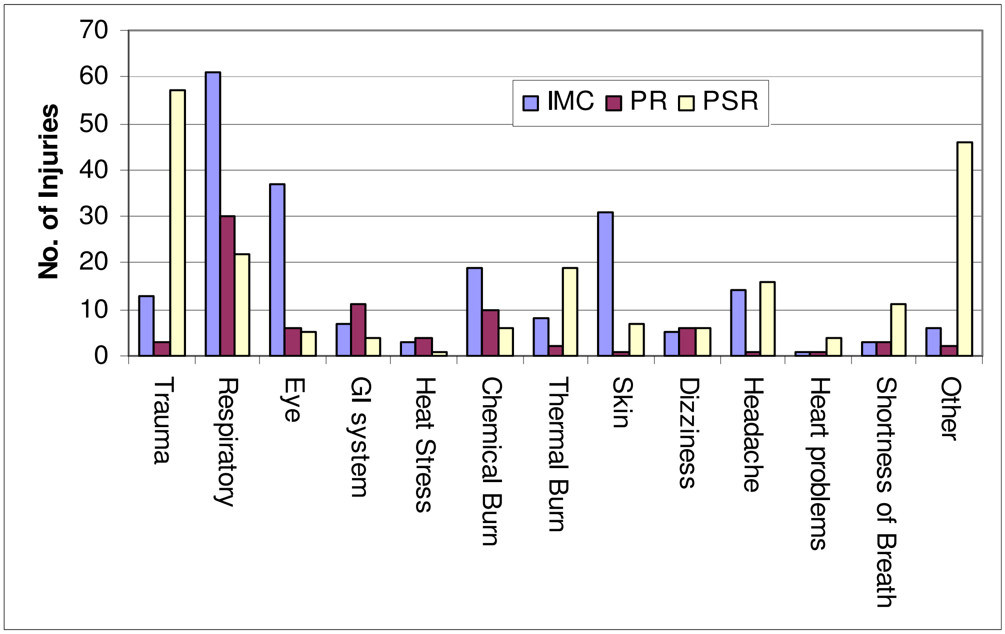
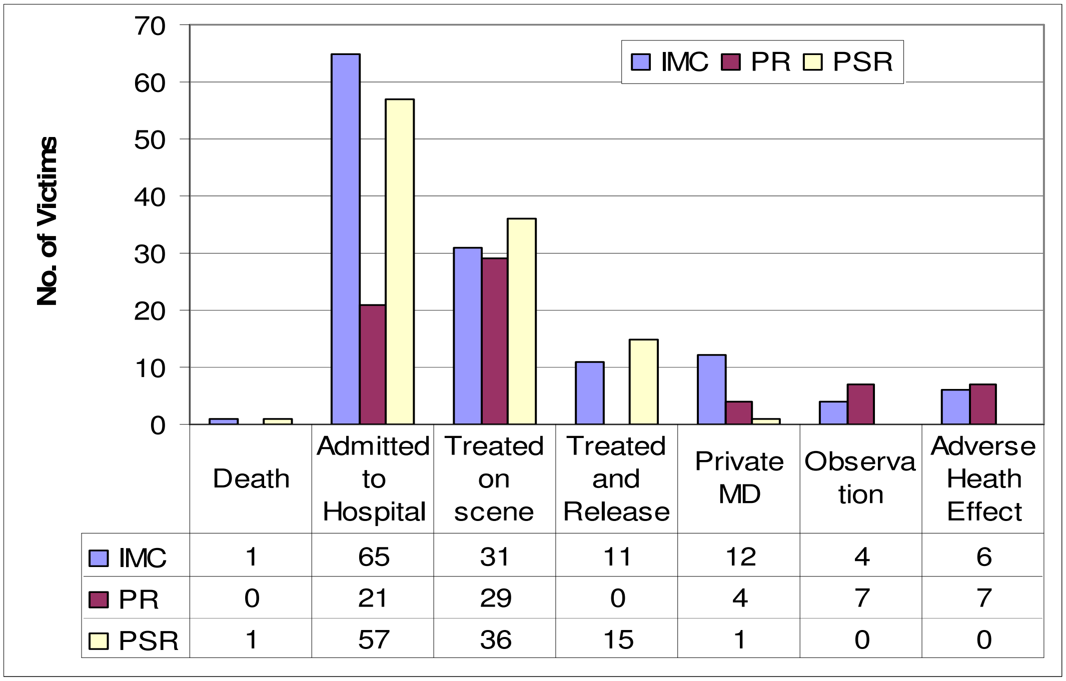


Figure 44. Distribution of type of injury in IMC, PR and PSR industries (Source: HSEES, 2000-2004)

Figure 44 represents distribution of type injury in IMC, PR and PSR industries during 2000-2004 in Texas. Type of injuries for IMC, PR and PSR industries are given below:

- IMC: Respiratory irritation 29%, Eye 18%, Skin 15%, Chemical burn 9%, Headache 7%, Trauma 6%, Thermal burn 4%, Gastrointestinal problem 3%
- PR: Respiratory irritation 38%, Gastrointestinal problem 14%, Chemical Burn 13%, Dizziness 8%, Eye irritation 8%, Trauma 4%
- PSR: Trauma 28%, Respiratory irritation 11%, Thermal burn 9%, Headache 8%, Shortness of breath 5%, Skin 3%, Dizziness 3%, other 23%.

7.11. Severity of Injury to Victims



	Death	Admitted to Hospital	Treated on scene	Treated and Release	Private MD	Observa tion	Adverse Heath Effect
IMC	1	65	31	11	12	4	6
PR	0	21	29	0	4	7	7
PSR	1	57	36	15	1	0	0

Figure 45. Distribution of victim severity in IMC, PR and PSR industries (Source: HSEES, 2000-2004)

Figure 45 shows the severity of victims for IMC, PR and PSR industries during 2000-2004. The majority of victims were treated at a hospital and treated on the scene for those three industries.

Table 7. Selection of personal protective equipment (Source: HSEES, 2000-2004)

Facility Type	Victims		PPE Level				Other PPE						None
	Type	No.	Level "A"	Level "B"	Level "C"	Level "D"	Gloves	Eye	Hard Hat	Shoes	FFTG	other	
	Employee	30		3		23	3	1					
	G. Public	19											19
	P. Firefighter	2									2		
	EMRCT	17		3	1	8		1	1	1	4		
PR	Total	68	0	6	1	31	3	2	1	1	6	0	19
	Employee	49	4	1	0	8	5	11	5	12			16
	G. Public	61	0	0	0	2	0	19	10	1		9	19
	P. Firefighter	4									4		
	V. Firefighter	14					5				7	1	1
	Responder	2				2							
IMC	Total	130	4	1	0	12	10	30	15	13	11	10	36
	Employee	95	0	0	1	1	2	84	6	6	2	1	4
	G. Public	4										4	
	P. Firefighter	4									4		
	EMRCT	7						5			2		
PSR	Total	110	0	0	1	1	2	89	6	6	8	5	4

Table 7 represents the types of personal protective equipments that were used by victims during the incidents.

The types of personal protective equipments used by workers are given below:

- Level “D” 77%, level “B” 10%, gloves 10%, and eye protection 3% in the Petroleum Refining industries.
- None 33%, steel-toed shoes 24%, eye protection 22%, level “D” 16%, level “A” 8%, and level “B” 2% in the Industrial and Miscellaneous Chemical industries.

- Eye protection 88%, hard hat 6%, steel-toed shoes 6%, level “C” 1%, level “D” 1%, gloves 2%, firefighter turn-out gear 2%, and none 4% in the Plastic, Synthetic and Resin industries.

The types of personal protective equipments used by general public are

- 0% in the PR industries
- Eye protection 31%, level “D” 3%, hard hat 16%, other 15% and none 31% in the IMC industries.
- Other (Firefighter turn-out gear without respiratory protection) 100% in the PSR industries.

Most of the firefighters used firefighter turn-out gear during the emergency situation. Appropriate personal protective equipments (PPE) should be used when handling hazardous chemicals. Level A should be used when the greatest level of skin, respiratory, and eye protection is required. Level B should be used when highest level of respiratory protection is needed. Level C should be used when the concentrations and types of airborne substances are known.

7.12. Evacuation Distribution

Table 8. Distribution of incidents by evacuation (Source: HSEES, 2000-2004)

Industry Type	Incident	Evacuation		PPL Evacuated	Avg. Hrs of Evacuation	Location				
		NO.	%			No defined Criteria	Circle /Radius	Downstream	Affected Building	Circle & Downwind
IMC	4258	28	0.66	4595	2.8	2	5	3	17	1
PR	2967	11	0.37	885	18.8	0	2	3	6	0
PSR	2031	5	0.25	670	3.8	0	2	1	2	0

Table 8 represents the incidents with evacuation and associated number of people evacuated, hours of evacuation, and location of evacuation in IMC, PR and PSR industries in Texas.

- Evacuations were ordered in 28 (0.66%) events in IMC industries involving 4595 people with an average 2.8 hours of evacuation.
- Evacuations were ordered in 11 (0.37%) events in PR industries involving 885 people with an average 18.8 hours of evacuation.
- Evacuations were ordered in 5 (0.25%) events in PSR industries involving 670 people with an average 3.8 hours of evacuation.

Most of the evacuation events were from a building or affected part of the building in those industries.

7.13. National Estimation

HSEES does not cover all the incidents in the US. Only thirteen to sixteen states participate in the HSEES incident reporting system. HSEES doesn't include petroleum related incidents. The HSEES data cover only 37% incidents in the US. This multiplier or Scaling ratio is used to estimate the total universe size which is shown in the table 9.

Table 9. National estimation of incidents (Source: HSEES, 2000-2004)

Year	Total Incidents HSEES Database	Scaling Ratio	Total Incidents National Estimate
2000	7548	2.7	20380
2001	8978		24241
2002	9014		24338
2003	9105		24584
2004	8111		21900

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Most of the incidents that are shown in the table 11 occurred in fixed facilities during 1993-2004. However, the number of transportation-related incidents has increased since data collection began. A majority of the fixed facility manufacturing incidents occurred in the Industrial and Miscellaneous Chemical (IMC) 55%, Petroleum Refining (PR) 25% and Plastic, Synthetic and Rubber (PSR) 15% industries during 2000-2004 in Texas. Texas counties along the gulf coast are highly industrialized and account for the largest number of incidents. Harris and surrounding counties account for 69% of the fixed facility manufacturing incidents in the Texas. The rate of incidents of Petroleum industries is higher than IMC and PSR industries. Some of the important points from the analysis are given below:

- Equipment failure is the major cause for both the interruption and comparison events. This study shows that majority of the incidents occurred involved ancillary process equipment, process vessels, and piping (Figure 32). Areas for further investigation should include equipment failures as the “primary” cause of the incidents. The definition of equipment used in the HSEES database is broad; therefore future study should focus on specific equipment failure. HSEES needs to collect detailed descriptions of the equipment. Database integration is an important step towards a comprehensive database. Information from different databases for the same incidents can be compiled after cleaning, transforming and mining of variables to get an integrated database. There are other databases which have detailed description of the equipment which can be used for collecting equipment description. Future study should be focused on data integration methodologies to effectively collect and integrate the data.

- Comparison events were more frequently caused by human error and less frequently caused by intentional acts than interruption events. Operator error can be reduced by an effective training and human factor management program. Analysis showed that a large number of incidents took place during startup/shutdown, and maintenance time. Most of the time, startup/shutdown and maintenance are planned work and are considered to be relatively higher risk phases. Intentional act is the major contributing factor of these events. This is because when people want to perform maintenance or startup/shutdown, they are fully aware that their actions will cause a release above permitted quantities. Careful monitoring and planning should apply during startup/shutdown and maintenance time. Standard operating procedures or a checklist for processes and better training can prevent or reduce those releases. Maintenance should also be considered during the design phase, ensuring that maintenance operations can be safely performed while the plant operation continues.
- Process upset is the number one interruption event occurring in those three industries. Study showed the rate of process upset events is higher than any other events. Equipment failure is the number one cause of the process upset events.
- Bad weather is the second most contributing factor of the power failure events in those three industries. Backup power generation system, improved process control engineering, and better emergency planning can reduce the power failure events. The role of weather should be further investigated.
- More incidents occurred on weekdays than weekends in the IMC, PR and PSR industries. Most of the maintenance events occurred during shift changes and peaked during the 8 a.m-10 a.m. shift. The Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) standard can keep reduce maintenance incidents if properly followed.

- A large percentage of injuries (IMC 30%, PR 38%, PSR 11%) involving respiratory irritation occurred among the workers (IMC 38%, PR 44%, and PSR 86%). Most of the workers involved in injuries during the incidents used level "D" type personal protective equipment, which provides minimal protection. It is really important to understand the nature of the chemicals while selecting PPE's for employees. A majority of the injuries were associated with the release of mixture, inorganic substances, and volatile organic compounds. Properties of mixtures such as reactivity, flammability, and toxicity must be studied to understand the nature of the releases. Industries should improve their emergency management plan and employee training program. Appropriate PPE should be selected based on the nature of the releases.
- The petroleum refining industries took longer time for evacuation than the IMC and PSR industries. This study shows that most of the victims are employees and general public. Better evacuation plans with plant and local emergency departments along with in-place sheltering can help Petroleum Refining industries effectively protect people in case of emergency.

- There are not many victims associated with released chemicals, but the release amounts are high which is shown in tables 29-31. This could affect the environment and have long-term effects on public health. The environmental departments should be involved in this situation to outreach industries. It seems logical that large releases of pollutants to the environment are injuring a sensitive population (children, elderly, and asthmatics) which is an important issue.

In this study, recommendations are given based on trend analysis, cause analysis and consequence analysis from the HSEES database. Learning from the past incidents can definitely reduce future incidents. Using the stored knowledge from incident databases can facilitate learning. However, case histories have no value unless it is studied, understood, and used properly.

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APPENDIX

Table 10. Acronyms and abbreviations

Acronym	Meaning
IMC	Industrial and Miscellaneous Chemicals Industry
PR	Petroleum and Refinery Industry
PSR	Plastic Synthetic and Resin Industry
MF	Manufacturing Event
FF	Fixed Facility
T	Transportation
PV	Process Vessel
APE	Ancillary Process Equipment
WA/DA	Waste Area/Dump Area
MHA	Material Handling Area
SAG	Storage Above the Ground
SBG	Storage Below the Ground
INCIN	Incinerator
Unkn	Unknown
SS	Startup and Shutdown
ME	Maintenance Event
PU	Process Upset
PF	Power Failure
F&E	Fire and Explosion
EF	Equipment Failure
OE	Operator Error
Inen. Act	Intentional or illegal act
BW	Bad Weather
VOC	Volatile Organic Compound
In. Subs	Inorganic Substances
Ag. Chem.	Agriculture Chemical
G. Public	General Public

Table 10. Continued

Acronym	Meaning
P. Firefighter	Professional Firefighter
GI	Gastrointestinal problem
SR	Scaling Ratio
EMCRT	Employee is the member of the company response team
FFTG	Firefighter turn-out gear
PPE	Personal Protective Equipment
HSEES	Hazardous Substance Emergency Events Surveillance
NRC	National Response Center
IRIS	Incident Reporting Information System
ERNS	Emergency Response Notification System
ARIP	Accidental Release Information Program
HMIRS	Hazardous Materials Incident Reporting System
HLPAD	Hazardous Liquid Pipeline Accident Database
IMIS	Integrated Management Information System
EPA	Environmental Protection Agency

Table 11. Incident distribution by year (source: HSEES, 1993-2004)

Year	No. Participating State	Fixed Facility Event					Transportation Event			Total
		MF	Texas	% of total MF	NonMF	Total	MF	NonMF	Total	
1993	11	1752	915	52.23	1447	3199	47	587	634	3833
1994	12	1653	826	49.97	1668	3321	63	849	912	4233
1995	14	2593	1589	61.28	1680	4273	55	982	1037	5310
1996	14	2954	1958	66.28	1373	4327	51	1108	1159	5486
1997	13	3114	2150	69.04	1271	4385	49	1079	1128	5513
1998	13	3293	2297	69.75	1436	4729	63	1189	1252	5981
1999	13	3084	1985	64.36	1550	4634	59	1567	1626	6260
2000	15	3214	1846	57.44	2285	5499	81	1968	2049	7548
2001	16	3672	1888	51.42	3064	6736	82	2160	2242	8978
2002	15	3804	2202	57.89	2689	6493	100	2421	2521	9014
2003	15	3774	2114	56.01	3008	6782	106	2217	2323	9105
2004	13+Part AL,MS	2982	1653	55.43	2921	5903	86	2122	2208	8111

Table 12. Incident distribution by industry type (Source: HSEES and U.S. Census Bureau, 1993-2004)

Year	Total Fixed Facility MF Incidents	Texas MF Incidents	Type of industry											
			Industrial and Miscellaneous Chemical (IMC)				Petroleum Refining (PR)				Plastic, Synthetic and Resin (PSR)			
			SIC 281, 286, 289				SIC 291				SIC 282			
			Incidents	%	Indus tries	Incident Rate	Incidents	%	Indus tries	Incident Rate	Incidents	%	Indus tries	Incident Rate
1993	1752	915	563	61.53	476	1.18	122	13.33	50	2.44	119	13.01	80	1.49
1994	1653	826	454	54.96	474	0.96	119	14.41	51	2.33	153	18.52	78	1.96
1995	2593	1589	817	51.42	485	1.68	457	28.76	54	8.46	182	11.45	85	2.14
1996	2954	1958	1043	53.27	474	2.20	511	26.10	57	8.96	199	10.16	93	2.14
1997	3114	2150	1269	59.02	509	2.49	428	19.91	50	8.56	288	13.40	89	3.24
1998	3293	2297	1088	47.37	537	2.03	582	25.34	68	8.56	420	18.28	84	5.00
1999	3084	1985	829	41.76	551	1.50	572	28.82	57	10.04	440	22.17	104	4.23
2000	3214	1846	867	46.97	532	1.63	463	25.08	51	9.08	384	20.80	89	4.31
2001	3672	1888	904	47.88	512	1.77	523	27.70	52	10.06	334	17.69	94	3.55
2002	3804	2202	993	45.10	502	1.98	643	29.20	64	10.05	480	21.80	102	4.71
2003	3774	2114	841	39.78	489	1.72	743	35.15	41	18.12	487	23.04	108	4.51
2004	2982	1653	653	39.50	503	1.30	595	36.00	54	11.02	346	20.93	91	3.80

Table 13. Distribution of interruption events by cause for Industrial and Miscellaneous Chemical (IMC) industry in TX (Source: HSEES, 2000-2004)

Total Incident	Type of Incident	Incident	Cause									
			E. Failure	O. Error	Inten. Act	ME	PF	SS	PU	Bad Weather	Other	Unknown
4258	**SS**	872	453	26	204	55	19	0	33	25	26	31
4258	**ME**	404	128	23	192	0	0	17	6	1	1	36
4258	**PU**	898	657	45	20	40	20	14	0	22	11	69
4258	**PF**	171	90	8	1	0	0	0	3	49	9	11
4258	**F&E**	39	28	1	0	0	3	0	1	0	4	2

Table 14. Distribution of interruption events by cause for Petroleum Refining (PR) industry in TX (Source: HSEES, 2000-2004)

Total Incident	Type of Incident	Incident	Cause									
			E. Failure	O. Error	Inten. Act	ME	PF	SS	PU	Bad Weather	Other	Unknown
2967	**SS**	521	273	10	115	15	12	0	19	10	6	61
2967	**ME**	276	99	4	144	0	0	4	2	0	0	23
2967	**PU**	997	801	18	26	17	23	7	0	23	13	69
2967	**PF**	155	107	4	1	1	0	0	1	24	4	13
2967	**F&E**	25	17	2	0	0	0	0	0	2	0	4

Table 15. Distribution of interruption events by cause for Plastic, Synthetic and Resin (PR) industry in TX (Source: HSEES, 2000-2004)

Total Incident	Type of Incident	Incident	Cause									
			E. Failure	O. Error	Inten. Act	ME	PF	SS	PU	Bad Weather	Other	Unknown
2031	**SS**	410	178	8	125	30	9	0	9	13	3	35
2031	**ME**	246	83	6	115	0	2	9	2	1	0	28
2031	**PU**	507	368	15	10	18	10	8	0	9	9	60
2031	**PF**	72	55	3	0	0	0	0	0	9	1	4
2031	**F&E**	16	8	2	0	0	0	0	0	2	4	0

Table 16. Distribution of comparison events by cause for IMC, PR and PSR industry in TX (Source: HSEES, 2000-2004)

Type of Industry	Comparison Event	Cause								
		E. Failure	O. Error	Inten. Act	ME	PF	SS	PU	Bad Weather	Other
IMC	1874	1103	210	15	110	31	103	182	55	65
PR	993	520	55	0	61	17	97	153	30	45
PSR	780	463	91	7	64	12	51	48	13	31

Table 17. Distribution incidents by Area/Equipment for IMC, PR and PSR industry (Source: HSEES, 2000-2004)

Type of Facility	Type of Incident	No. of Incident	Process Vessel	Ancillary Process Equipment (APE)	Piping	Material Handling Area (MHA)	Storage Above the Ground (SAG)	Dump Area (DA)	Transformer or Capacitor	Incinerator	Other
IMC	Interruption	2384	671	1285	262	14	65	12	7	46	22
	Comparison	1874	348	734	427	64	194	30	7	26	44
	Total	4258	1019	2019	689	78	259	42	14	72	66
PR	Interruption	1974	357	1387	166	3	32	2	4	14	9
	Comparison	993	206	529	134	13	78	11	1	6	15
	Total	2967	563	1916	300	16	110	13	5	20	24
PSR	Interruption	1251	488	608	114	0	22	2	4	5	8
	Comparison	780	195	313	167	16	62	5	1	2	19
	Total	2031	683	921	281	16	84	7	5	7	27

Table 18. Distribution of interruption and comparison events by month (Source: HSEES, 2000-2004)

Type of Incident	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	Total
Interruption	452	395	429	465	459	500	478	450	419	527	533	502	5609
Comparison	332	251	347	287	309	295	283	310	287	317	318	311	3647

Table 19. Distribution of events by month for IMC, PR and PSR industry (Source: HSEES, 2000-2004)

Type of Facility	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	Total
IMC	374	292	363	361	340	349	335	382	351	387	365	359	4258
PR	259	203	236	220	259	273	225	227	230	261	287	287	2967
PSR	150	145	181	172	169	175	199	154	124	195	200	167	2031

Time Distribution by Day

Table 20. Distribution of events by day for IMC, PR and PSR industries (Source: HSEES, 2000-2004)

Sat	Sun	Mon	Tues	Wed	THR	FRI	Total
1083	1036	1455	1455	1486	1410	1331	9256

Table 21. Distribution of maintenance events by time for IMC, PR and PSR industries

0:00 - 1:59	2:00- 3:59	4:00- 5:59	6:00- 7:59	8:00- 9:59	10:00- 11:59	12:00- 13:59	14:00- 15:59	16:00- 17:59	18:00- 19:59	20:00- 21:59	22:00- 23:59	Total
74	53	48	95	139	98	81	100	62	55	59	62	926

Table 22. Distribution of events by number of chemical released for IMC, PR and PSR industries (Source: HSEES, 2000-2004)

Facility	Incidents	No of Chemical Released								Total Chemical
		1	2	3	4	5	6	11	13	
IMC	4258	4219	34	3	1	0	0	0	1	4313
PR	2967	2961	4	0	0	0	2	0	0	2981
PSR	2031	2019	10	0	0	1	0	1	0	2055

Table 23. Distribution of events by release locations of different chemicals and associated victims for IMC industries in Texas (Source: HSEES, 2000-2004)

Chemical Categories	No. of incidents	No. of Incidents With Victims	No. of Victims	Location of Release								
				PV	Pipe	APE	MHA	SAG	SBG	WA	INCIN	Other
Acid	89	5	13	10	42	7	5	8	9	0	0	2
Ammonia	70	2	9	13	17	17	2	3	18	1	0	0
Base	60	3	44	15	16	2	4	9	7	2	0	6
Chlorine	19	1	1	2	13	1	1	0	1	0	0	1
Inorganic substances	760	2	21	187	52	481	7	12	8	2	8	9
VOC	774	5	26	144	184	274	18	62	46	22	6	25
Mixture	2221	10	47	579	295	1165	26	70	30	6	40	28
Ag. Chemicals Pesticides	92	1	10	17	22	21	1	10	4	2	15	0
Other	141	2	2	52	28	28	8	10	14	3	3	2
Unknown	84	1	1	18	23	18	5	11	0	4	0	2

Table 24. Distribution of events by release locations of different chemicals and associated victims for PR industries in Texas (Source: HSEES, 2000-2004)

Chemical Categories	No. of Incidents	No. of incidents With Victims	No. of Victims	Location of Release							
				PV	Pipe	APE	MHA	SAG	WA	INCIN	Other
Acid	28	1	4	3	14	2	4	3	0	0	0
Ammonia	39	0	0	33	0	33	0	0	0	0	0
Base	13	0	0	1	6	2	0	4	0	0	0
Chlorine	4	0	0	0	1	0	0	3	0	0	0
Inorganic substances	1175	2	5	219	69	856	0	12	0	12	7
VOC	328	1	2	58	67	125	5	53	10	1	9
Mixture	1359	6	44	277	139	894	3	26	3	7	10
Other	20	1	2	1	5	3	2	6	0	0	3
Unknown	14	1	17	2	3	2	2	6	1	0	0

Table 25. Distribution of events by release locations of different chemicals and associated victims for PSR industries in Texas (Source: HSEES, 2000-2004)

Chemical Categories	No. of Incidents	No. of incidents With Victims	No. of Victims	Location of Release							
				PV	Pipe	APE	MHA	SAG	WA	INCIN	Other
Acid	28	1	4	3	14	2	4	3	0	0	0
Ammonia	39	0	0	33	0	33	0	0	0	0	0
Base	13	0	0	1	6	2	0	4	0	0	0
Chlorine	4	0	0	0	1	0	0	3	0	0	0
Inorganic substances	1175	2	5	219	69	856	0	12	0	12	7
VOC	328	1	2	58	67	125	5	53	10	1	9
Mixture	1359	6	44	277	139	894	3	26	3	7	10
Other	20	1	2	1	5	3	2	6	0	0	3
Unknown	14	1	17	2	3	2	2	6	1	0	0

Table 26. Distribution of events by type of victim for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

Industry	Employee	Responder	General Public	Profe-ssional Firefighter	Volunteer Firefighter	EMCRT	Total
IMC	49	2	61	4	14	0	130
PR	30	0	19	2	0	17	68
PSR	95	0	4	4	0	7	110

Table 27. Distribution of events by severity of victim for IMC, PR and PSR industries in Texas (Source: HSEES, 2000-2004)

TYPE	IMC	PR	PSR	Total
Death	1	0	1	2
Treated on scene	31	29	36	96
Treated at Hospital (Admitted)	65	21	57	143
Treated at Hospital (Not Admitted)	11	0	15	26
Observation at Hospital, No treatment	4	7	0	11
Seen by private Physician within 24hrs	12	4	1	17
Adverse Health Effects experienced within 24 hrs	6	7	0	13
Total	130	68	110	308

Table 28. Distribution of events by type injury for IMC, PR and PSR industries in Texas

(Source: HSEES, 2000-2004)

Injury Type	**IMC**	**PR**	**PSR**
Trauma	13	3	57
Respiratory	61	30	22
Eye	37	6	5
Gastrointestinal system	7	11	4
Heat Stress	3	4	1
Chemical Burn	19	10	6
Thermal Burn	8	2	19
Skin	31	1	7
Dizziness or other central nervous system	5	6	6
Headache	14	1	16
Heart problems	1	1	4
Shortness of Breath	3	3	11
Other	6	2	46
Total	208	80	204

Table 29. Distribution of most chemical release by substance name and associated release amount, victims for IMC industries in Texas (Source: HSEES, 2000-2001)

Name	No. of events	Max(LB)	Avg.(LB)	Min(LB)	Victim
Acrolein	34	19	3.4	1	0
Ammonia	32	9124	739.4	13	3
Benzene	9	6750	337	6750	0
Butadiene	38	2757	109.5	9	0
Carbon Black	11	10	467.8	4400	0
Carbon Monoxide	19	99000	23531.2	10	0
Carbon Tetrachloride	10	8764	1404.5	14	0
Chlorine	7	570	227.7	39	1
Chlorodifluormethane	20	3000	900.2	26	0
Ethylene	13	18200	7981.3	260	0
Hydrogen Sulfide	18	6834	794	99	0
Mixture	880	10	7971	10	30
Nitric Oxide	189	4145	653	9	0
Nitrogen dioxide	11	7234	574	9	0
Nitrogen oxide (NOX)	18	1238	231.5	11	0
Oxide of Nitrogen NOS	75	10692	577.6	12	0
Sodium Hydroxide	23	135460	15423.5	70	0
Sulfur Dioxide	58	89083	6330	9	1
Sulfuric Acid	23	166500	16777.7	100	2
Vinyl Chloride	11	3000	340.4	2	0
Ethylenediamine	1	13000	13000	13000	23

Table 30. Distribution of most chemical release by substance name and associated release amount, victims for PR industries in Texas (Source: HSEES, 2000-2001)

Name	No. of Events	Max(LB)	Avg. (LB)	Min (LB)	Victim
Ammonia	7	15095	3673.1	313	0
Benzene	39	900	83.2	10	0
Butadiene	21	763	155.3	11	0
Carbon Black	3	21504	7658	210	0
Carbon Monoxide	9	90517	26050.7	11050	0
Ethylene	4	13260	6536.3	126	0
Hydrogen Sulfide	34	15154	1083.2	99	0
Mix: H2S,Nitric oxide, S02	9	71793	23775.5	4024	0
Mix: Nitric/Nitrogen di oxide	11	1683	248.3	9	0
Mix: Nitric/Sulfur di oxide	33	9234	3115	12	0
Mix: H2S/S02	63	66264	14369	25	0
Nitric Oxide	77	5430	227.2	9	0
Nitrogen dioxide	29	5340	346.1	9	0
Nitrogen oxide (NOX)	11	3522	703.1	10	0
Oxide of Nitrogen NOS	67	3418	565	11	
Sulfur Dioxide	105	71441	5263.3	9	0
Sulfuric Acid	10	2561.568	2561.6	138.2	4

Table 31. Distribution of most chemical release by substance name and associated release amount, victims for PSR industries in Texas (Source: HSEES, 2000-2001)

Name	No. of Events	Max (LB)	Avg.(LB)	Min (LB)	Victim
Ammonia	18	837	246.2	26	0
Benzene	22	934	185.6	14	0
Butadiene	35	11492	529.8	11	91
Chlorine	3	300	111.3	16	1
Carbon Monoxide	6	21489	7810.2	591	0
Chlorodifluormethane	7	10500	3533	150	0
Cyclohexane	6	25454	5827.3	150	90
Ethylene	18	15500	4779.9	50	0
MIX: Ammonia/Oxides of Nitrogen NOS	16	1350	699.4	44	0
MIX: Benzene/Butadiene	11	621	213.4	28	0
Nitric Oxide	24	307	74.7	11	0
Nitrogen dioxide	18	1425	331.3	14	0
Nitrogen oxide (NOX)	8	50	27.3	11	0
Oxide of Nitrogen NOS	54	2778	239.4	12	0
Propylene	23	4347	739	17	0
Styrene	3	8905	5353	1801	94
Vinyl Chloride	28	7058	379.9	1	0

VITA

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